a group intro

Taciroglu Research Group

UCLA



Ertugrul Taciroglu

Professor & Chair
5731E Boelter Hall
Department of Civil and Env. Engineering
University of California
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etacir@ucla.edu

Phone: (310) 267-4655

Education

University of Illinois at Urbana-Champaign, PhD, 1998
University of Illinois at Urbana-Champaign, MS, 1995
Istanbul Technical University, Turkey, Eng, 1993

Research Areas

Computational Solid & Structural Mechanics, Structural health-monitoring, Inverse problems, Soil-structure interaction, Performance-based Earthquake Engineering

Honors

ASCE Engineering Mechanics Institute, Fellow, 2015
ASCE Walter Huber Research Prize, 2011
National Science Foundation CAREER Award, 2006

Service

Managing Editor, ASCE J. Structural Engineering
Associate Editor, ASCE J. Engineering Mechanics
Associate Editor, EERI Earthquake Spectra
Editorial Board Member, Structural Control & Health Monitoring
Editorial Board Member, Soil Dynamics & Earthquake Engineering

Sponsors

National Science Foundation — Where Discoveries Begin
California Department of Transportation
PEER — Pacific Earthquake Engineering Research Center
Lawrence Livermore National Laboratory — Science in the National Interest
The California Energy Commission
endo pharmaceuticals — an endo international company
U.S. Army
Fulbright
The Getty Research Institute
USGS — science for a changing world
CGS — California Geological Survey
LACMA — Los Angeles County Museum of Art
TÜBİTAK
China Scholarship Council
Tokyo Institute of Technology



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Research Scientists / Post-doctoral Researchers (4)

Fariba Abazarsa (system ID, structural health-monitoring)
Mohamad Alipour (machine learning, wildfire modeling)
Barbaros Cetiner (computer vision, machine learning, regional hard simulation)
Farid Ghahari (system ID, structural health-monitoring)
Wenyang Zhang (soil-structure interaction)

Ph.D. Students (7)

Yufeng Dong (Soil-foundation-structure interaction problems in High-Speed Rail applications)

Shuochuan Meng (Regional performance-based wind hazard assessment—buildings)
Viviana Vela (Regional performance-based seismic assessment—woodframe structures)

Arezoo Rezavizadeh (Constitutive Modeling of Natural Hydraulic Lime)

Elias Gueidon (Application of the material point method for nonlinear dynamic soil behavior)
Sultan Aldakhil (material point method & its applications to geotechnical problems)

Mustafa Cetinkaya (Performance-based seismic design of accelerated-construction bridges)



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Alumni

Peng-Yu Chen, PhD 2021, Assistant Professor, **National Central University**, Taiwan

Henan Mao, PhD 2021, Engineer at **ANSYS**, San Diego CA

Arastoo Dasmeh, PhD 2019, Project Engineer at **SpaceX**, Los Angeles CA.

Reza Ghotbi, PhD 2018, Project Eng. at **Englekirk** Structural Engineers, Los Angeles CA

Elnaz Esmaeilzadeh, PhD 2016, Assistant Professor at **University of Rena NV**.

Ali Nojoumi, PhD 2016, Applications Engineer at **COMSOL** Inc, Los Angeles CA.

Richard Gash, PhD 2015, Associate Professor at **United States Military Academy**, West Point, NY.

Jaedal Jung, PhD 2014, Research Scientist at **Teledyne Scientific & Imaging**, Los Angeles, CA.

Massimiliano Repupilli, PhD 2012, Structural/CAE/Composites Engineer, **AlphaSTAR Corp.**, Long Beach, CA.

Rani Harb, PhD 2011, FEA Project Engineer at **e-Xstream Engineering — an MSC Company**, Ann Arbor, MI.

Roshanak Omrani, PhD 2010, Data Scientist at **Bitvore**, Irvine CA.

Payman Khalili-Tehrani, PhD 2009, Principal Engineer at **SC Solutions**, Sunnyvale, CA.

William Elmer VII, PhD 2009, Defense Systems Analysis Group, **LLNL**, Livermore, CA.

Can Alpdogan, PhD 2008, R&D Manager, Structural Mechanics Team Manager at **FİGES A.Ş.**, Istanbul, Turkey.

Jing Zhao-Stafsudd, PhD 2007, Group Leader at **Raytheon Space & Airborne Systems**, El Segundo, CA.

Chengwen Liu, PhD 2006, Supervising Engineer at **WSP | Parsons Brinckerhoff**, Sacramento, CA.

Chang-soon Rha, PhD 2006, Professor, **Kookmin University**, Seoul, South Korea.



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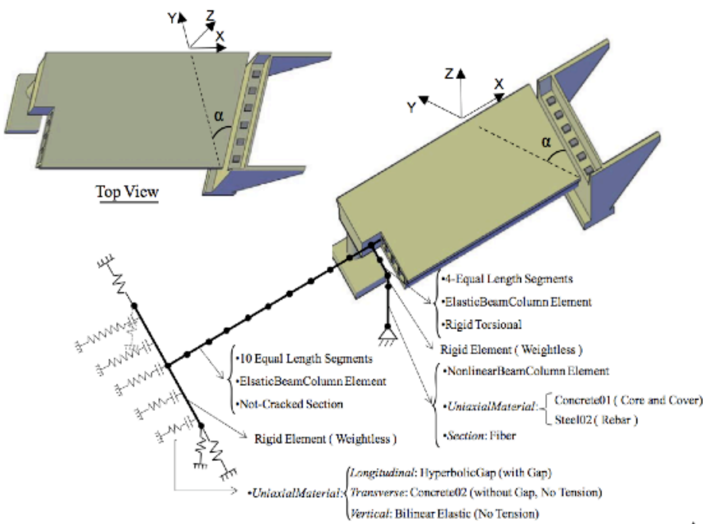
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Report will help Caltrans devise PBEE methods for bridges

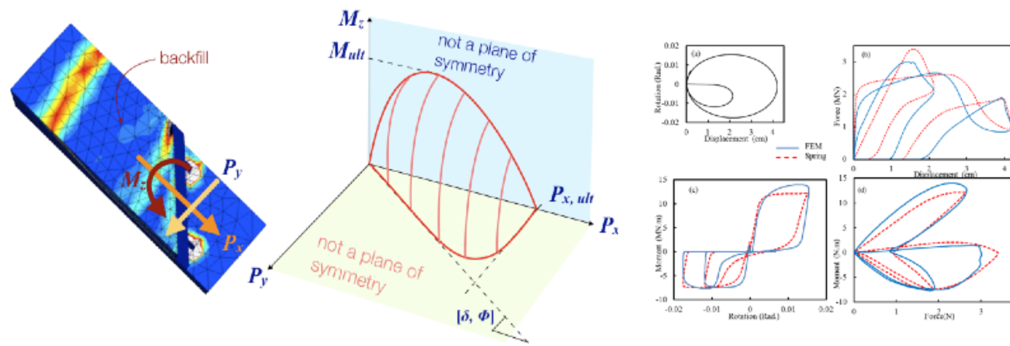


"Performance-based seismic assessment of skew bridges," PEER.

"Guidelines for nonlinear seismic analysis of ordinary bridges: version 2.0," Caltrans.

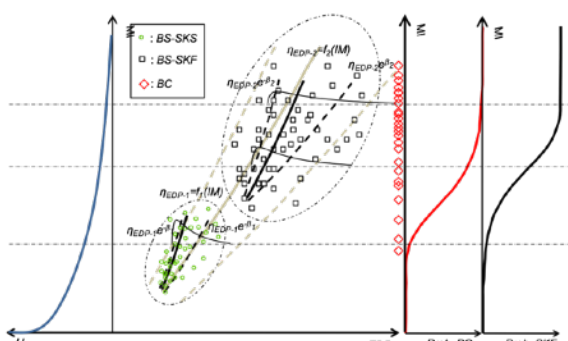


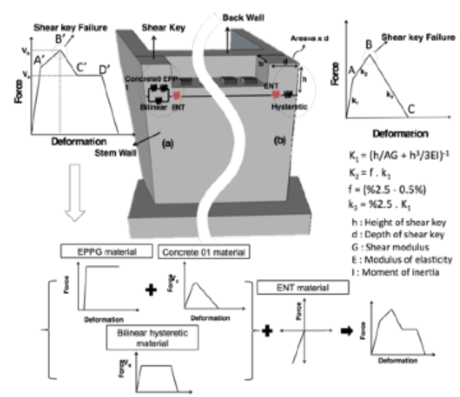
Nonlinear modeling in OpenSees



Development of accurate & efficient models for abutment response

New probabilistic framework for bridge PBEE →





Development of validated models for shear keys



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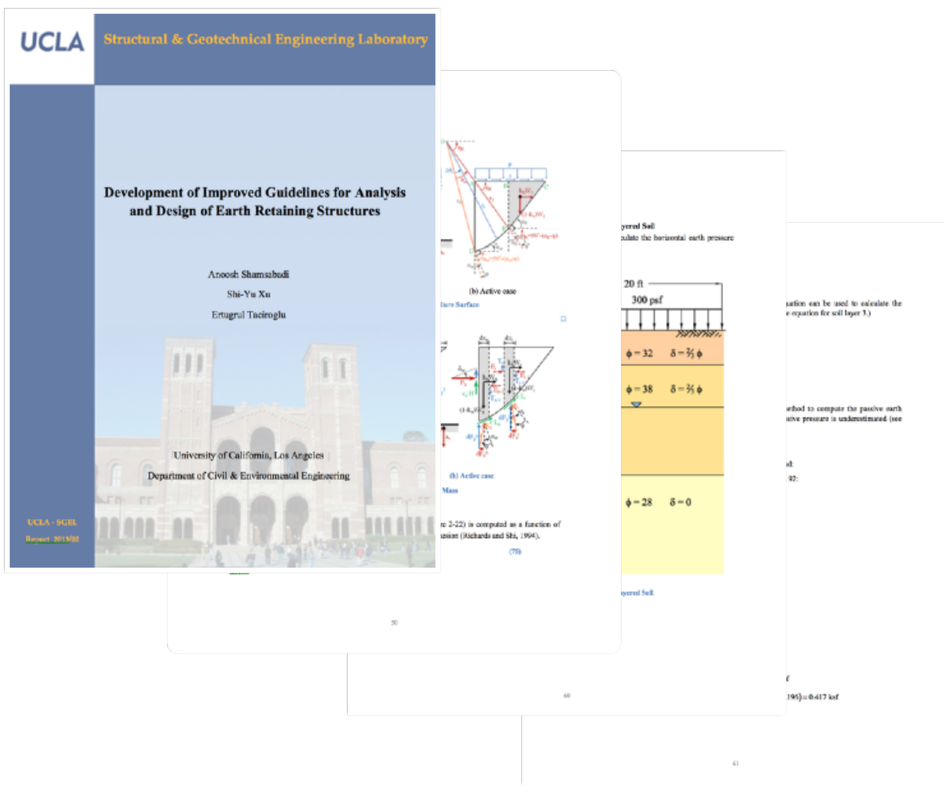
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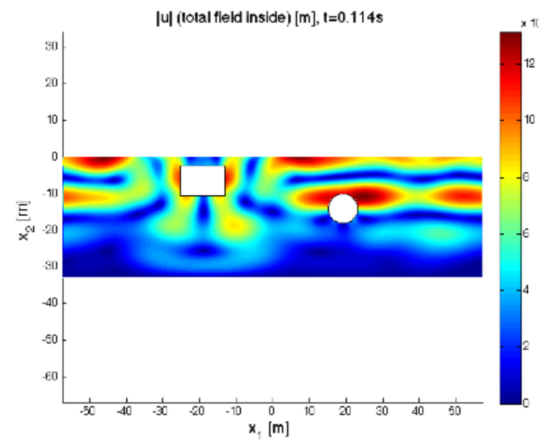
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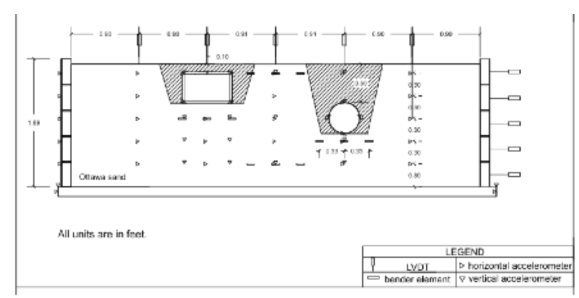
Report now forms the basis for a new Caltrans & High-Speed Rail Design Manual for Earth-Retaining Structures

"Development of Improved Guidelines for Seismic Analysis and Design of Earth Retaining Structures," Caltrans

"Development of Validated Methods for Soil-Structure interaction of Buried Structures," Caltrans









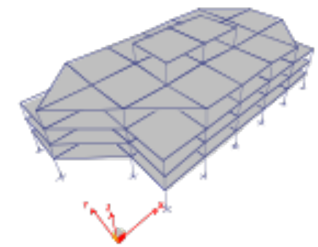
Ertugrul Taciroglu

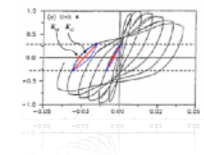
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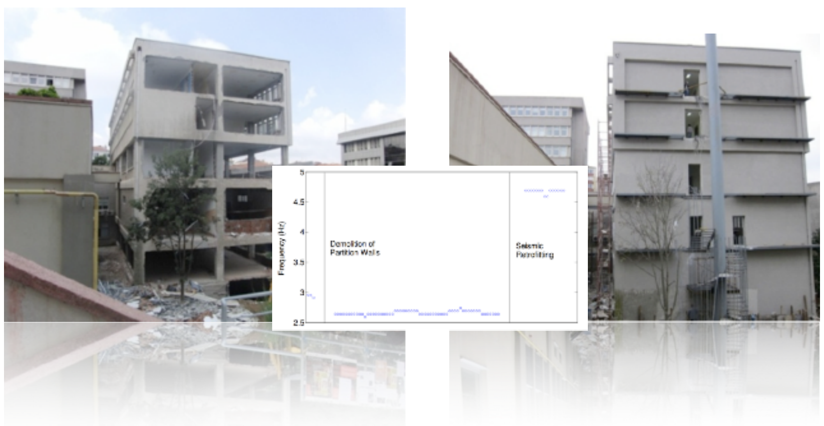
"Forced vibration testing of a 4-story building damaged during 1994 Northridge Earthquake" NSF





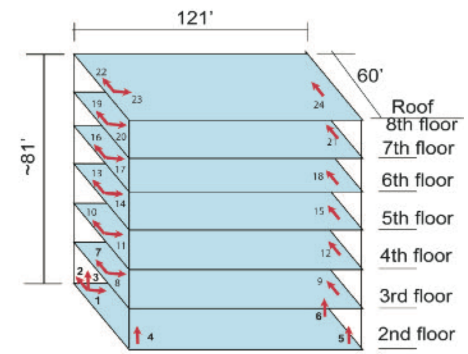


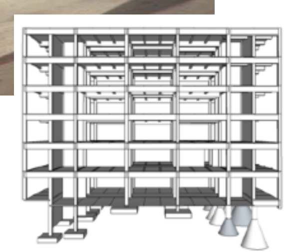
"Forced and ambient vibration testing of a masonry-infill RC building before and after retrofit" NSF



"Seismic instrumentation of Boelter Hall" USGS





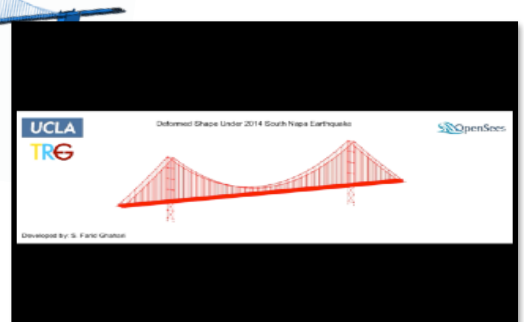


Note 1: Figure not to scale
Note 2: Numbering system is for demonstration only. It maybe changed
Note 3: Sensors on each of the 3rd, 4th, 5th, 6th, 7th 8th (roof) levels can be mounted on the ceiling below that floor

FIGURE 1/2 (June 22, 2012)

"Spatial variability of seismic input motions for bridges affected by the 2014 Napa Valley Eq." California Geological Survey





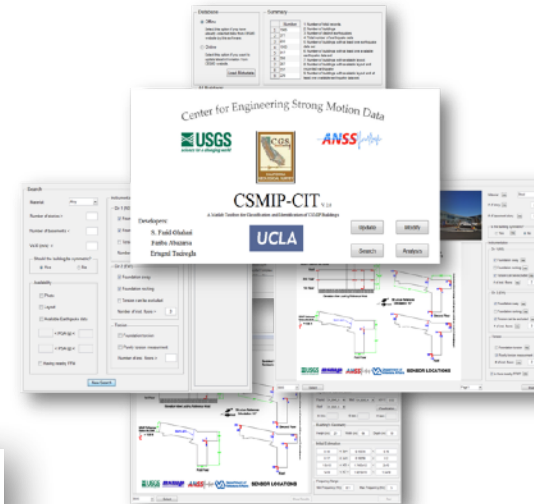


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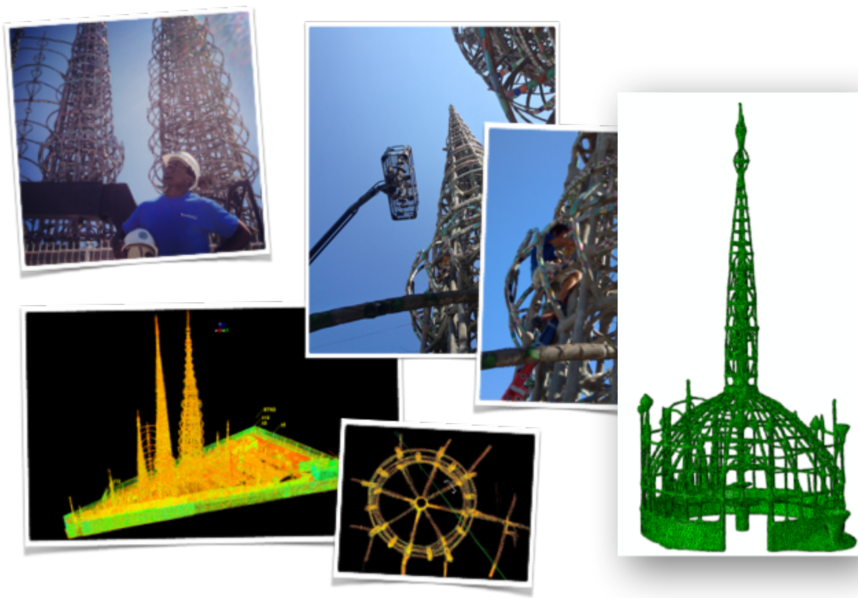
Phone: (310) 267-4655

"System Identification of soil-structure interaction in buildings," California Geological Survey

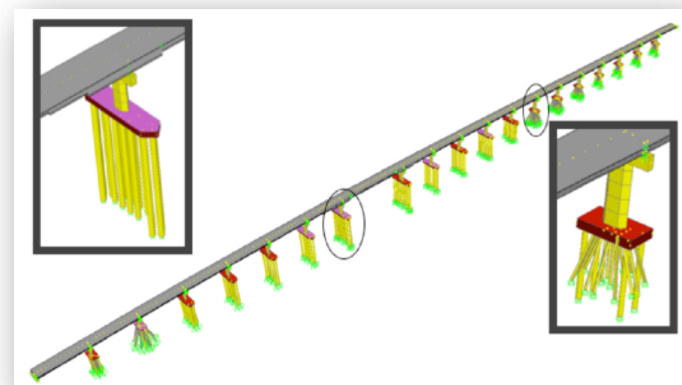


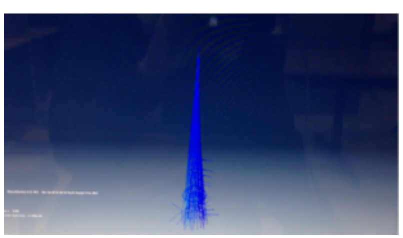


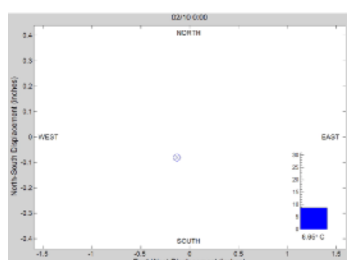
"Wind, thermal and seismic monitoring of the Watts Towers" NSF + LACMA

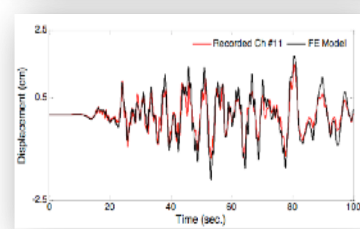


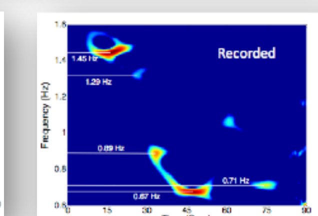
""Field testing and model validation of the Samoa Bridge" Caltrans





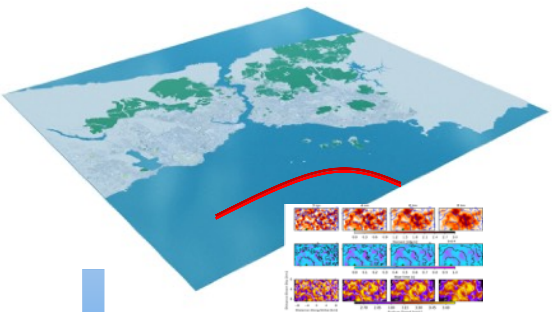




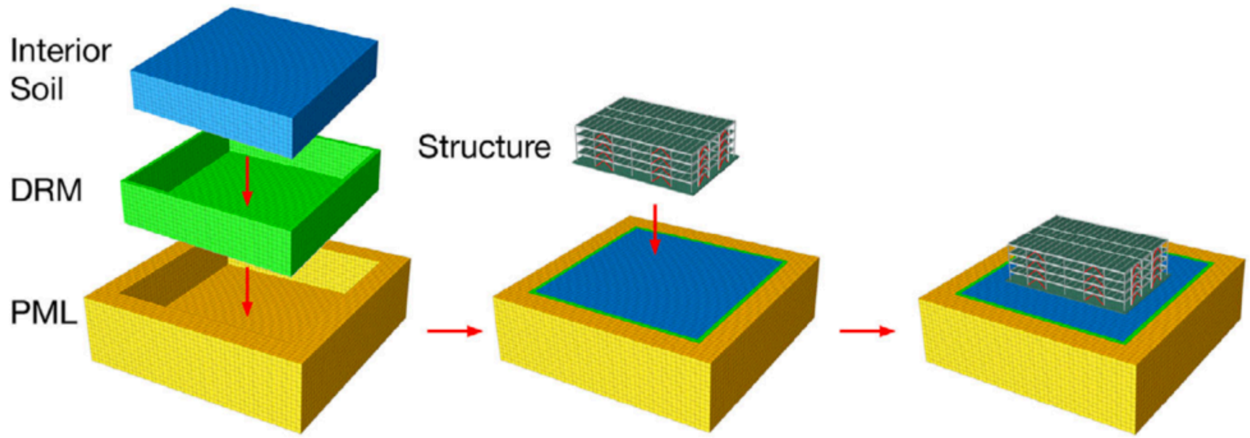


Rupture-to-rafters

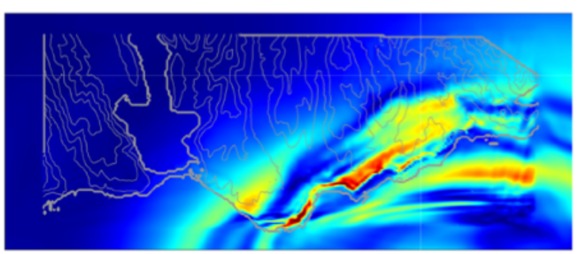
Regional-scale domain



Local analyses of critical infrastructure



Physics-based ground motion simulation (Hercules)

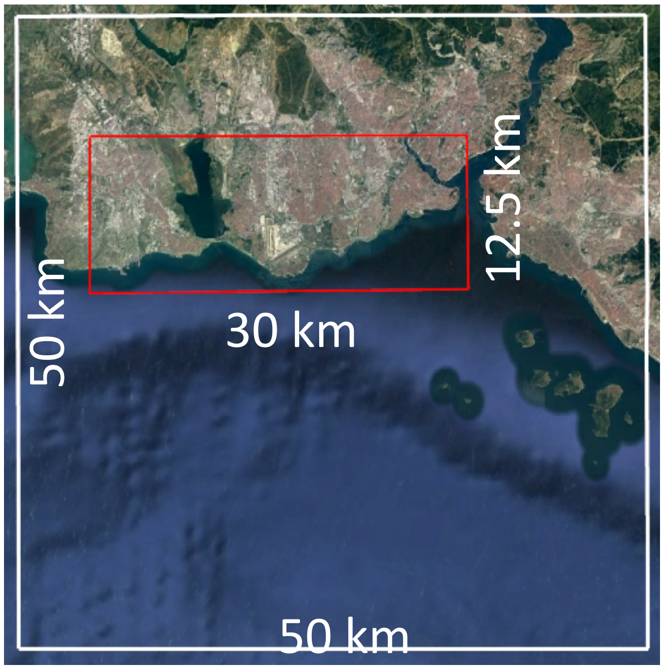


Infrastructure model inventories



Physics-based large-scale ground motion simulation

Istanbul model: 50 km by 50 km by 25 l

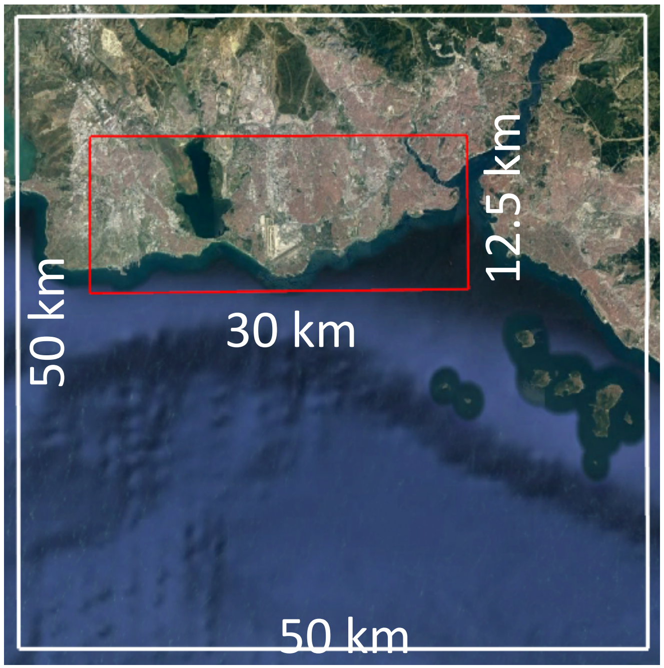


Simulations were performed using Hercules on Frontera / Stampede (TACC)

Model parameter	Linear	Linear + topography	Nonlinear	Nonlinear + topography
(Hz)	16.4	16.4	8.2	8.2
(m/s)		250		
Points per wavelength		10		
Min element size (m)	~1.5	~1.5	~3	~3
Number of elements (billions)	8.4	11.1	5.4	7.2
Number of nodes (billions)	8.48	11.60	5.48	7.48
Time-step (s)	0.0004	0.0004	0.0004	0.0004
Simulated duration (s)		30		
Number of cores	8400	8400	22400	28000
Core usage time (hours)	11.1	16.6	33.5	47.5

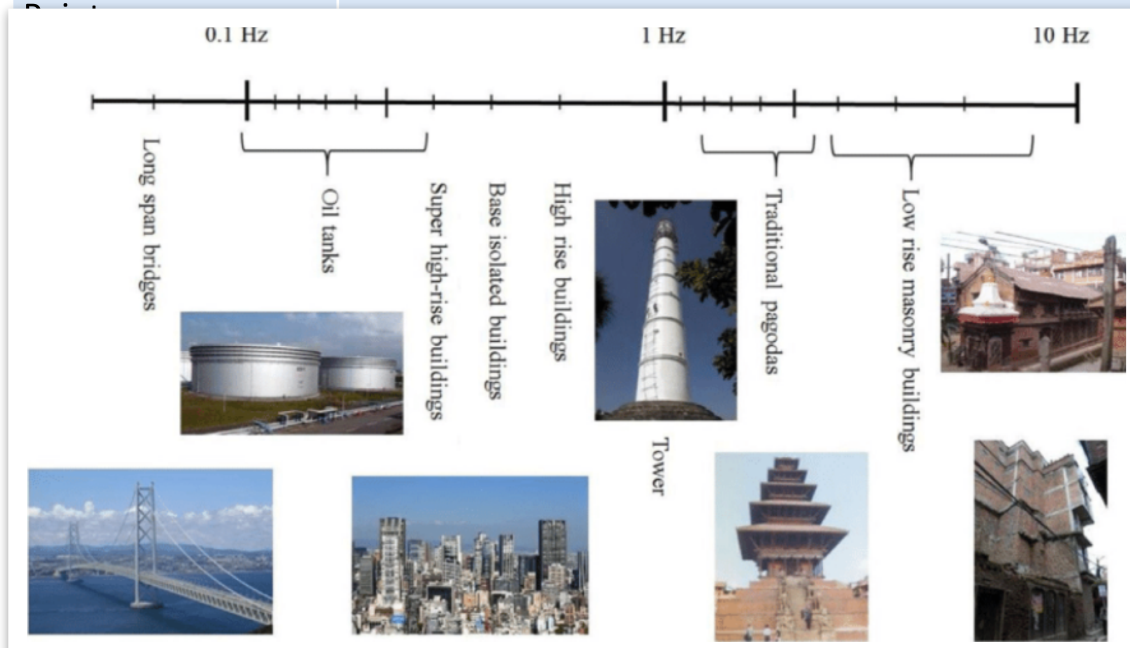
Physics-based large-scale ground motion simulation

Istanbul model: 50 km by 50 km by 25 k



Simulations were performed using Hercules on Frontera / Stampede (TACC)

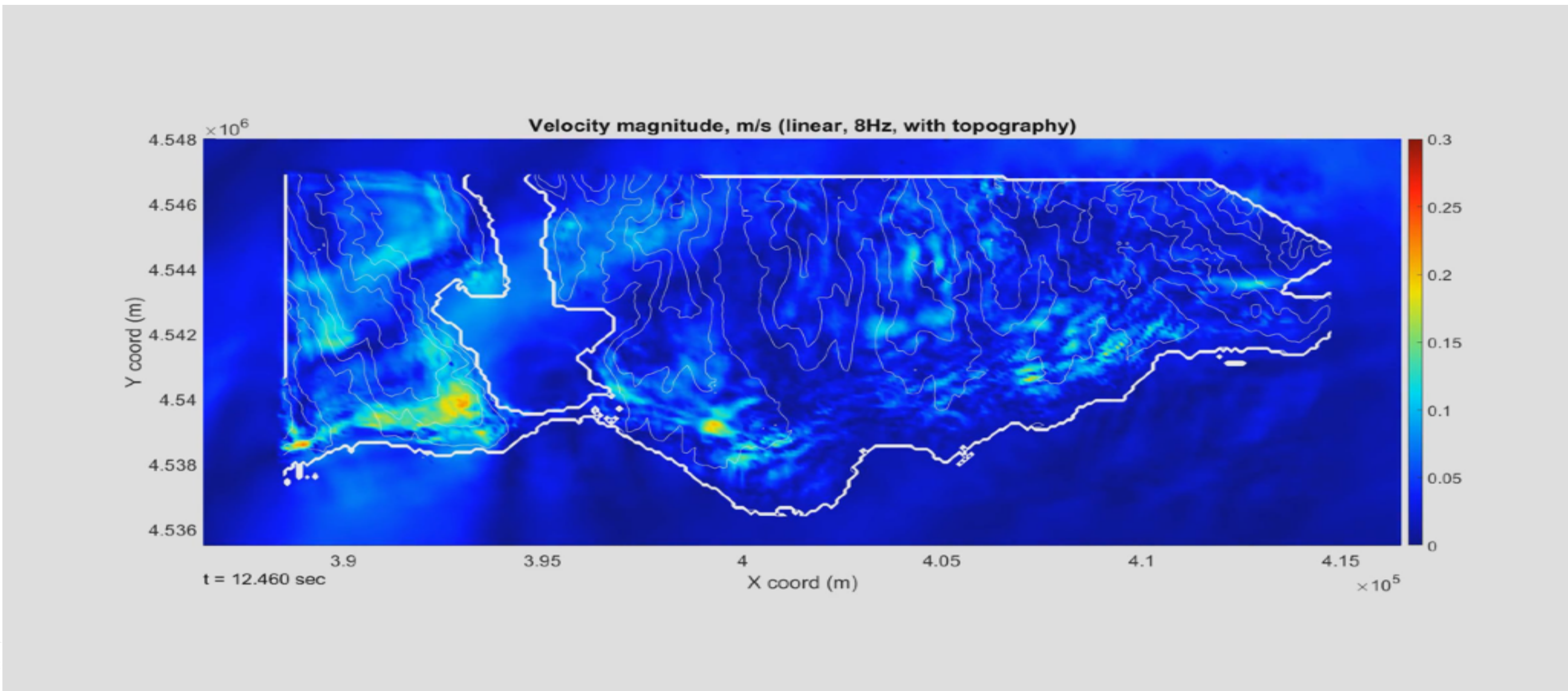
Model parameter	Linear	Linear + topography	Nonlinear	Nonlinear + topography
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(m/s)		250		
Core usage time (hours)	11.1	16.6	33.5	47.5



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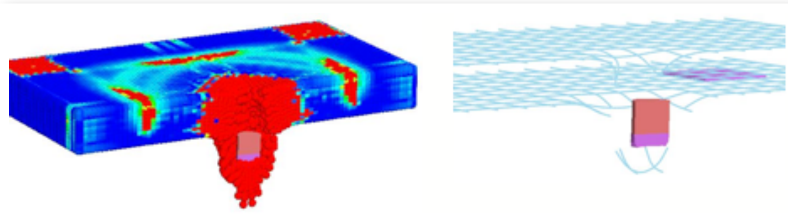
Physics-based large-scale ground motion simulation

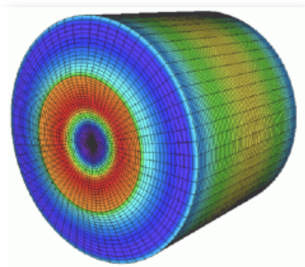
A scenario earthquake with a magnitude of 6.5

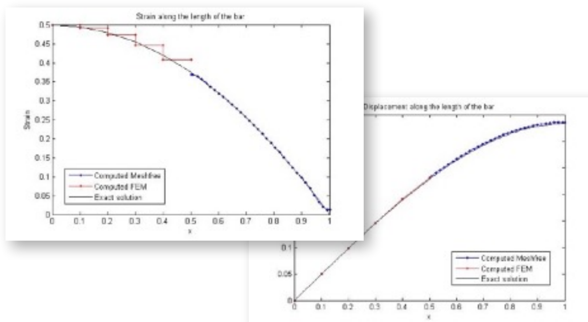


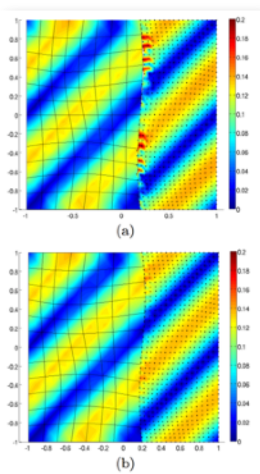
Recent or ongoing research

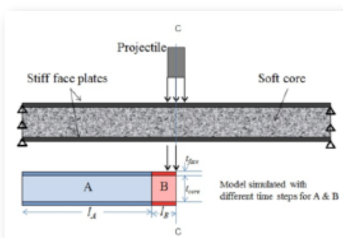
“Recursive, Adaptive Multilevel Analysis of Structures under Extreme Loads,” NSF-CAREER, Lawrence Livermore Nat’l Laboratory

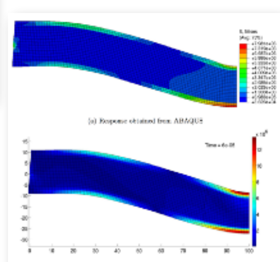












Recent publications

- Xu XB, Wang JT, Xu WY, Taciroglu E, Dai F, Peng W (2018). “A forensic investigation of the Tai-He arch bridge collapse,” Eng. Structures. (in print).
- Xu, S-Y, Pabodha KK, Kannagara M, Taciroglu E (2018). “Analysis of stress distribution across a retaining wall backfill.” Comp. & Geotechnics, 103, 13-25.
- Xu S-Y, Lawal AI, Shamsabadi A, Taciroglu E (2018). “Estimation of Static Earth Pressures for a Sloping Cohesive Backfill using Extended Rankine Theory with a Composite Log-Spiral-Rankine Method” Acta Geotechnica (in print).
- Esmaeilzadeh E, Jeong C, Dashti S, Hushmand A, Taciroglu E (2018). “Seismic response of buried reservoir structures: a comparison of numerical simulations with centrifuge experiments.” Soil Dynamics and Earthquake Engineering, 109: 322-331.
- Ghahari SF, Abazarsa F, Jeong C, Kurtulus A, Taciroglu E (2018). “Blind Identification of Site Effects and Bedrock Motions from Surface Response Signals” Soil Dynamics & Earthquake Engineering, 107: 322-331.
- Ghahari SF, Abazarsa F, Taciroglu E (2018). “Probabilistic Blind Identification of Site Effects from Ground Surface Signals” Bull. Eq. Eng., 16(3): 1079-1104.
- Shirzad N, Mahsuli M, Ghahari SF, Taciroglu E (2018). “Bayesian identification of soil-foundation stiffness of building structures” Structural Control & Health Monitoring, 25(3): e2090.
- Celebi M, Kashima T, Ghahari SF, Koyama S, Taciroglu E (2017). “Before and after retrofit dynamic characteristics of a 55-story building,” Earthquake Spectra, 33(44), 1599-1626.
- Zhang W, Esmaeilzadeh Seylabi E, Taciroglu E (2017). “Validation of a three-dimensional constitutive model for nonlinear site response and soil-structure interaction analyses using centrifuge test data,” Int. J. Num. & Anal. Meth. Geomechanics, 41, 1828–1847.
- Gash R, Esmaeilzadeh E, Taciroglu E (2017). “Discrete-time digital filters for approximating frequency-dependent foundation impedance functions in the time-domain and their stability analysis,” Soil Dyn. Eq. Eng., 94 223-233.
- Esmaeilzadeh E, Kurtulus A, Stokoe II K, Taciroglu E (2017). “Interaction of a pile with layered-soil under vertical excitations: Field experiments versus numerical simulations,” Bulletin of Eq. Engineering (in print, doi:10.1007/s10518-017-0099-5).
- Peng W, Zhao H, Dai F, Taciroglu E (2017). “Analytical method for overturning stability analysis of single-column pier bridges” ASCE J. Performance of Const. Facilities, 04017007-16.

Big Data — A New Research Frontier in Earthquake Engineering

regional seismic risk and rapid post-event assessment

by

Ertugrul Taciroglu, Professor
Civil & Environmental Engineering Department
University of California, Los Angeles

Faculty Affiliate, *UCLA B. John Garrick Institute for the Risk Sciences*

Big Data — A New Research Frontier in Earthquake Engineering

regional seismic risk and rapid post-event assessment

with contributions from

B Cetiner, A Ghotbi, SF Ghahari,
PY Chen, W Zhang, E Esmaeilzadeh

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Caltrans

PEER

25 YEARS INSTITUTE OF TRANSPORTATION STUDIES ITS

CGS CALIFORNIA GEOLOGICAL SURVEY

Big Data — A New Research Frontier in Earthquake Engineering

regional seismic risk and rapid post-event assessment






Big Data — A New Research Frontier in Earthquake Engineering

regional seismic risk and rapid post-event assessment






Outline

- Big picture
- Applications
  - Regional PBSA of bridge networks
  - Regional PBSA of RC buildings
  - *Rapid-post event assessment*
- Ingredients (what we already have + *missing bits*)

Big Picture

Why large-scale assessment?



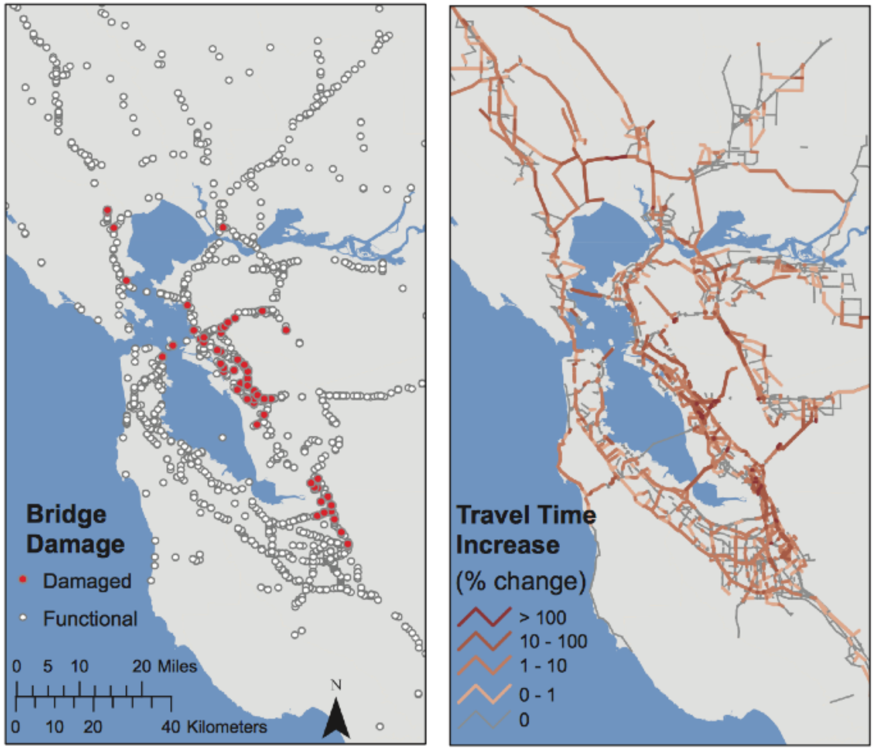
- Hazards affect regions. The big picture is needed for
  - Actuarial plans (insurance companies)
  - Urban planning & public policy (government)
  - Emergency service planning (1st responders)
- Built environment is highly interconnected
  - Residential neighborhoods, business centers
  - Transportation networks
  - Lifelines (water, power, communications)



Challenges

- Data ☞ metadata ☞ models
  - Diverse sample population (requires sophisticated—and as of yet non-existent—data harvesting tools)
  - Access to detailed data may be not be possible (requires estimation missing data, machine learning)
  - Processing requires *large* computational resources (would break records for civil engineers)
- Models ☞ decision variables
  - Heterogeneous analysis tools (OpenSees, OpenSHA, PACT)
  - New tech needs to be brought in (data analytics, Bayesian inference, etc.)

Objectives

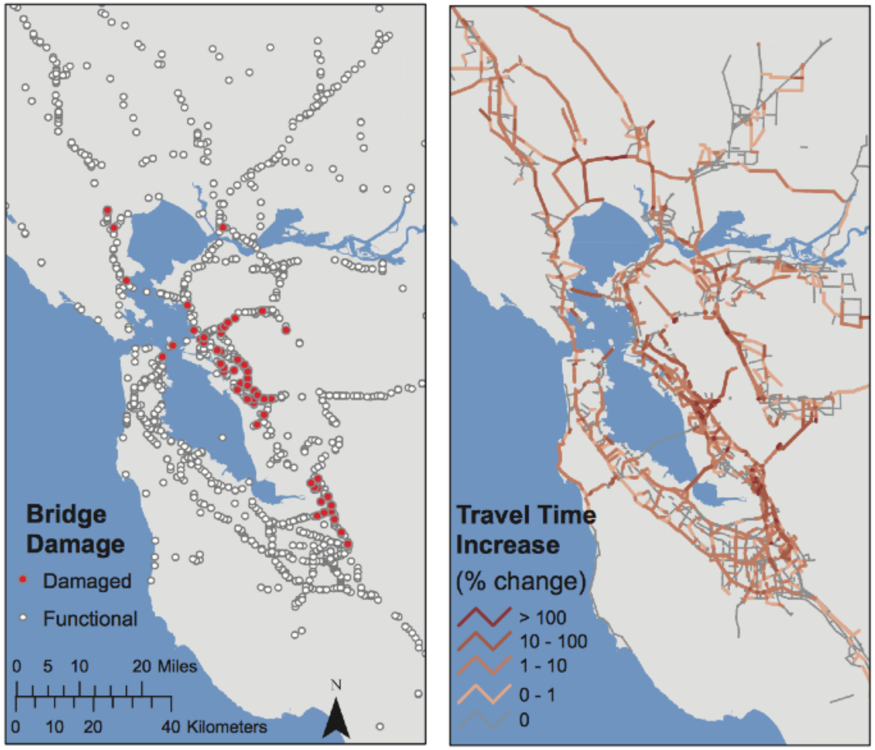


Risk framework for a highway network (Miller & Baker, 2015)

Develop (semi-) automated interactive platforms that can evaluate seismic vulnerability of complex networks:

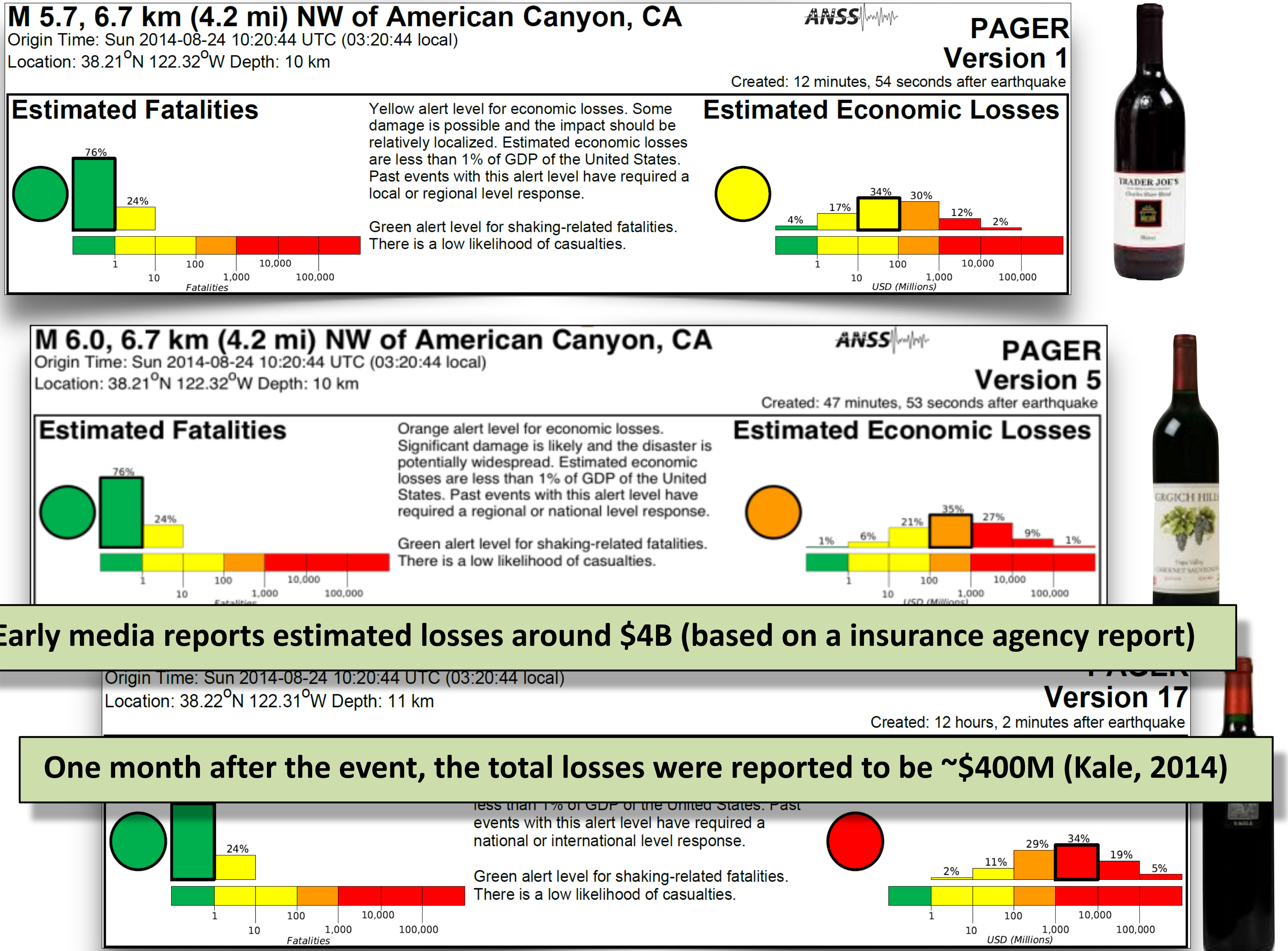
1. Generate structural models using data harvested from various sources
2. Carry out site- and structure-specific seismic analyses
3. Evaluate the consequent economic losses at the network-level

Objectives



Risk framework for a highway network
(Miller & Baker, 2015)

Existing predictive computational tools and IT capabilities allow *unprecedented granularity* for such seismic risk and loss assessment studies



Early media reports estimated losses around $4B (based on a insurance agency report)

One month after the event, the total losses were reported to be ~$400M (Kale, 2014)

Vision and Scope


UCLA Regional PBSA Tool
Image and direct metadata from users and public databases
Image-to-Model Module
meta-data-bases for structural system and nonstructural components, loss estimates
compute
commit
visualize
amazon web services
OPEN SHA
NGA W2
OpenSees
FEMA PACT
Google Sketch-up
Google earth

Where will the data come from?

- National Bridge Inventory (NBI) by FHWA
- *Caltrans Bridge Database*
- California Strong Motion Instrumentation Program (CSMIP) Database





Number of Spans	20
Plan Shape	Straight
Total Length	2507' (764.1m)
Width of Deck	34' (10.4m)
Construction Year	1971
Instrumentation Year	1996
Seismic Retrofit	2006







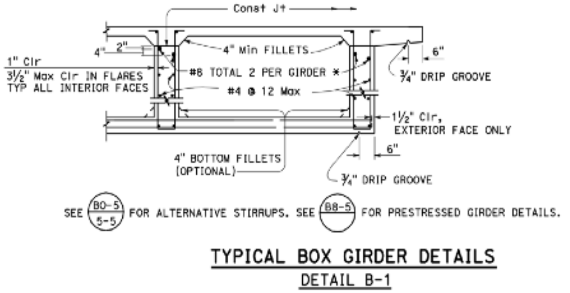


Where will the data come from?

Guideline Documents

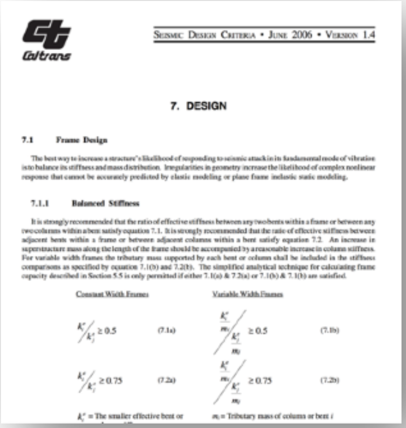
- Caltrans Standard Plans

  allow determination of many metadata elements (e.g., abutment seat length, shear-key reinforcement, foundation configuration, etc.)



- Caltrans Seismic Design Criteria Manual (Caltrans SDC)

  provides era-specific information on component and system design

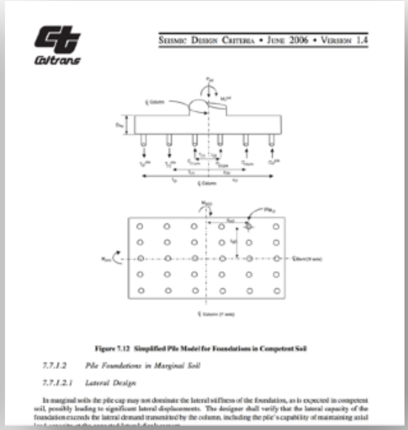


Seismic Design Criteria • June 2006 • Version 1.4

7. DESIGN

7.1 Frame Design

7.1.1 Balanced Stiffness



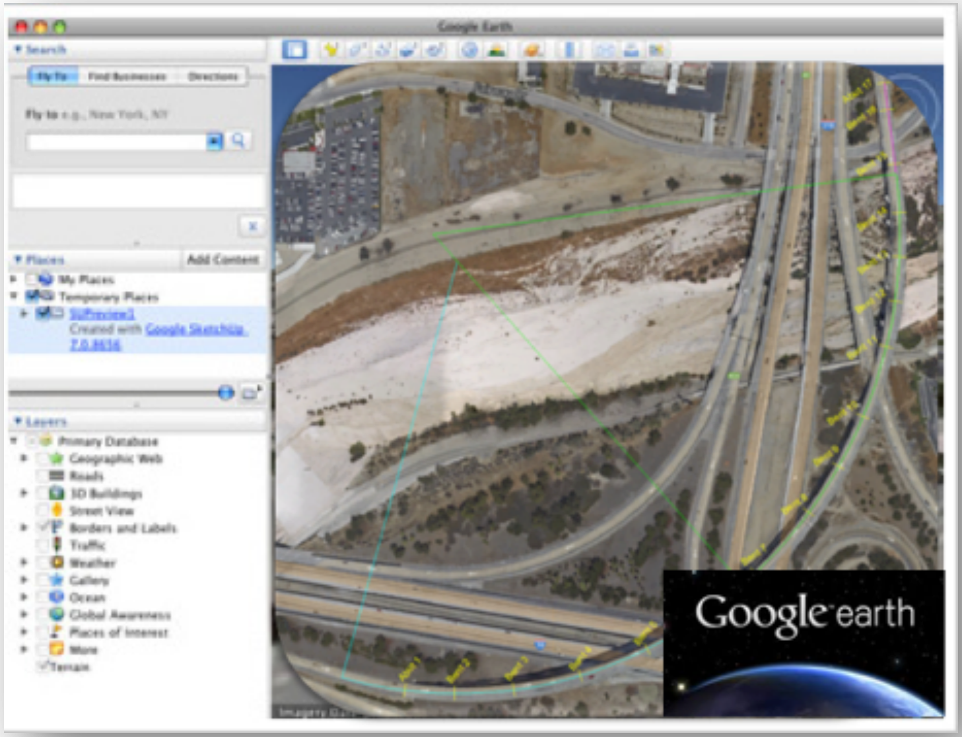
Seismic Design Criteria • June 2006 • Version 1.4

Where will the data come from?

Internet Harvesting

- Google Maps/Earth, MapQuest, etc.

  can be interrogated online
  more on this later …



Where will the data come from?

Internet Harvesting

- Crowd Sourcing
  - uses human intelligence when algorithms are too difficult to devise
  - wikipedia-type consensus models can be built (contributors v. referees)

Typical Seat Abutment

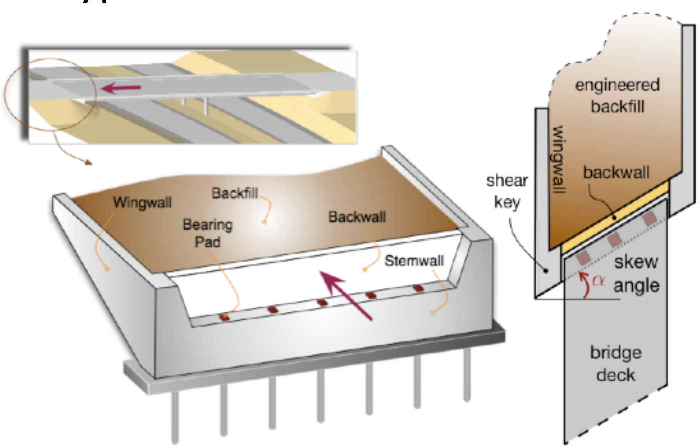




Image to Model

Detection of Bridge Locations

Read approximate bridge coordinates from NBI

→ Extract a satellite image of the location corresponding to approximate bridge coordinate

→ Run a road extraction algorithm to detect roads on the selected image

↓ Generate random points on detected continuous road lines and pass coordinates to Google Roads API

← Cross-check route inventory with NBI, then highlight the relevant road line

← Prompt user to mark beginning and end points

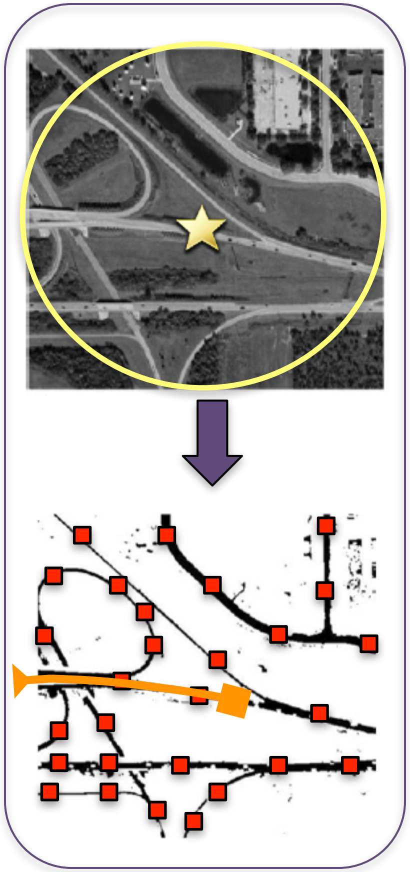


Image to Model

Developing the Wireframe Bridge Models

Create up to 1000 sampling points between user-defined coords.

→ Snap points to road centerline curve using Google Maps

→ Determine ground elevations using Google Maps

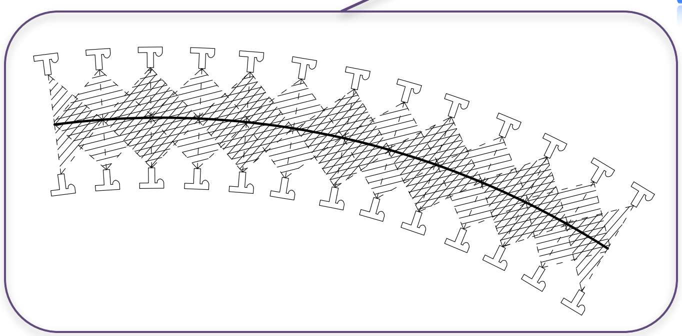
→ Determine road elevations using MapQuest

Create virtual cameras from bridge centerline curve

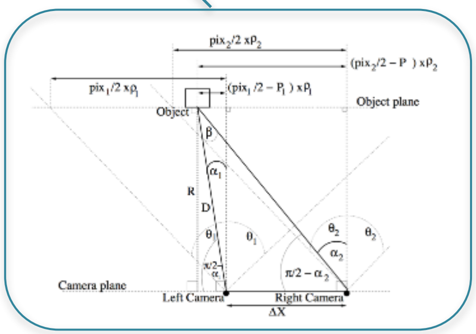
→ Harvest Street View images at each virtual camera location from Google Street View

→ Identify bent locations using stereo pair images

Establish wireframe bridge model



A typical virtual camera configuration for a curved bridge



Distance estimation for an object using a stereo pair image

Image to Model

Determination of Deck Properties

Determine deck type, top width of deck and year the structure was built from NBI

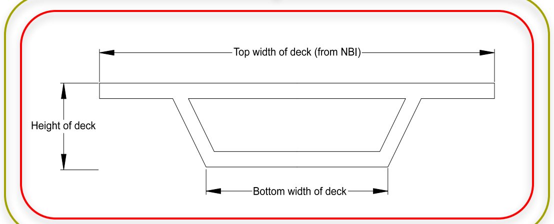
Determine desk superelevation profile by combining geometry info. and speed limit data

Estimate bottom width and height by utilizing fuzzy logic edge detection on harvested Street View images

Estimate reinforcement detailing and corresponding structural properties

Standard Specifications for Highway Bridges

Google Maps





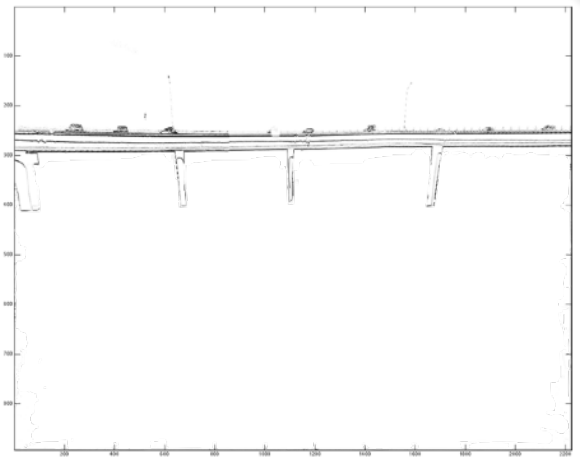


Image to Model

Determination of Column Properties

21.2.1.2 Column Reinforcement Requirements

(1) Longitudinal Reinforcement

Maximum Longitudinal Reinforcement Area, $A_{st,\max} = 0.04 \times A_g$ (*SDC* 3.7.1-1)

Minimum Longitudinal Reinforcement Area:

$A_{st,\min} = 0.01(A_g)$ for columns (*SDC* 3.7.2-1)

$A_{st,\min} = 0.005(A_g)$ for Pier walls (*SDC* 3.7.2-2)

where:

A_g = the gross cross sectional area (in.^{2})

Normally, choosing column $A_{st} = 0.015(A_g)$ is a good starting point.

(2) Transverse Reinforcement

Either spirals or hoops can be used as transverse reinforcement in the column. However, hoops are preferred (see *MTD* 20-9) because of their discrete nature in the case of local failure.

Determine the column type based on the number of detected column edges

↓

Sample column height and width at a number of levels

↓

Estimate rebar detailing and corresponding structural properties by interrogating a database of similar columns (and by utilizing Caltrans SDC)



Image to Model

Completion of model using crowdsourced data, metadata harvested from the databases

Abutment types

↓

Column bearing types

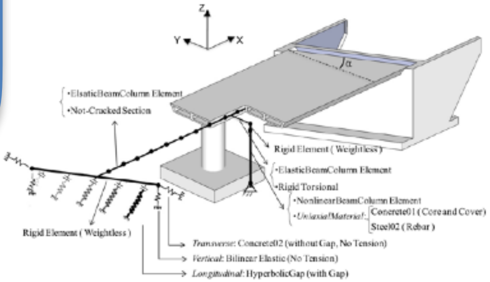
↓

Shear key types and locations

↓

Complete model

Data to be refined by utilizing meta-data rules *learned* from Caltrans Standard Plans, Caltrans SDC via Deep Learning



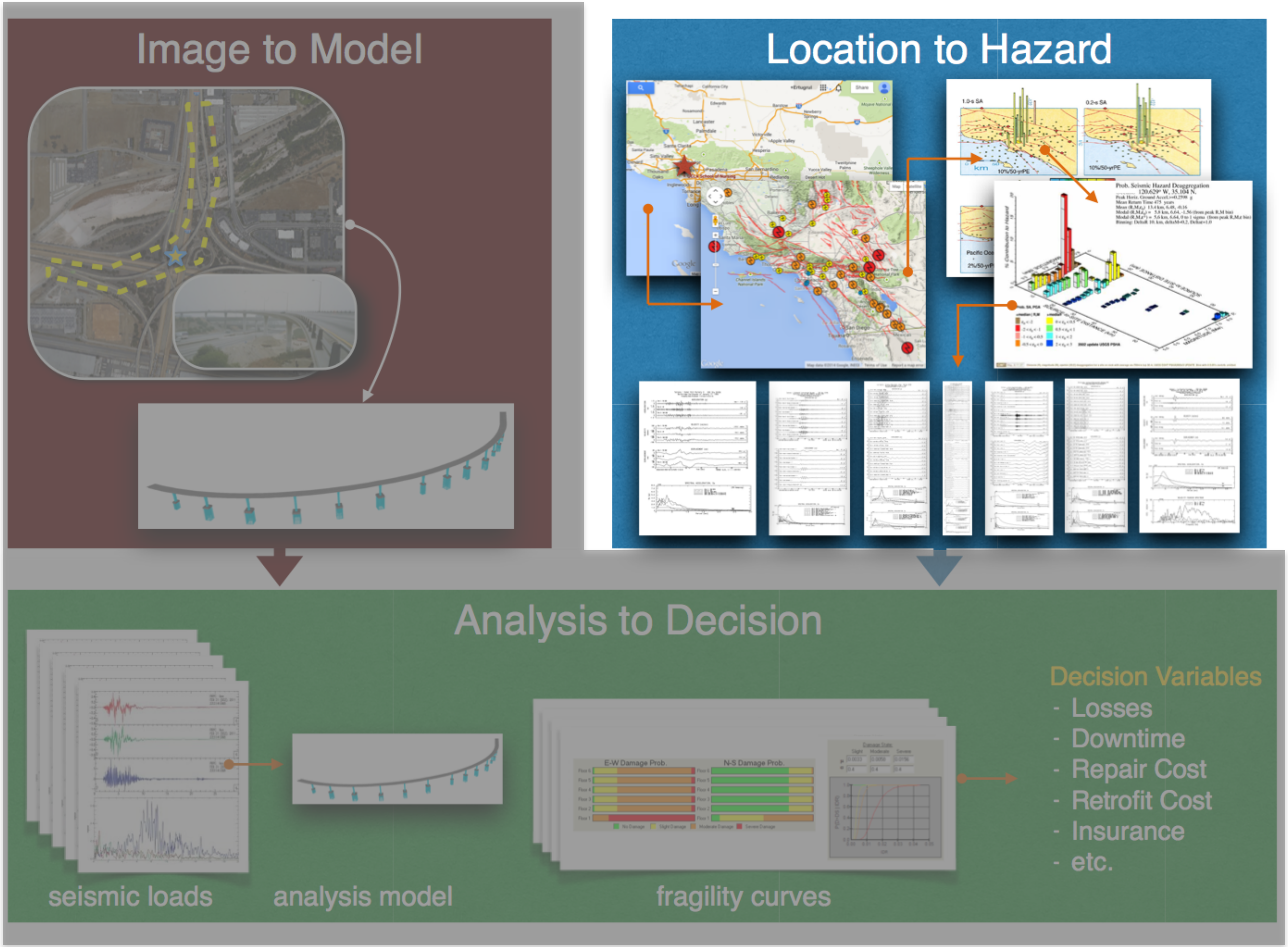
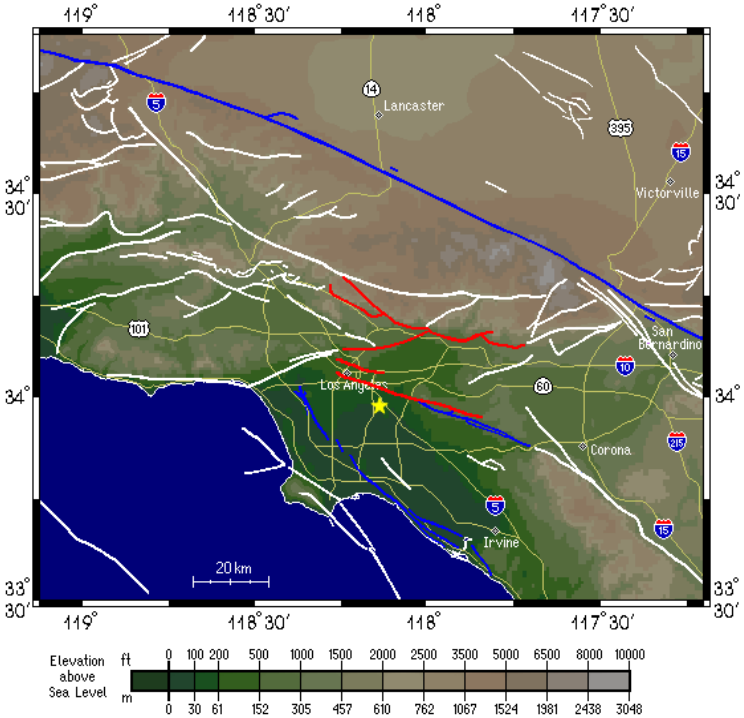


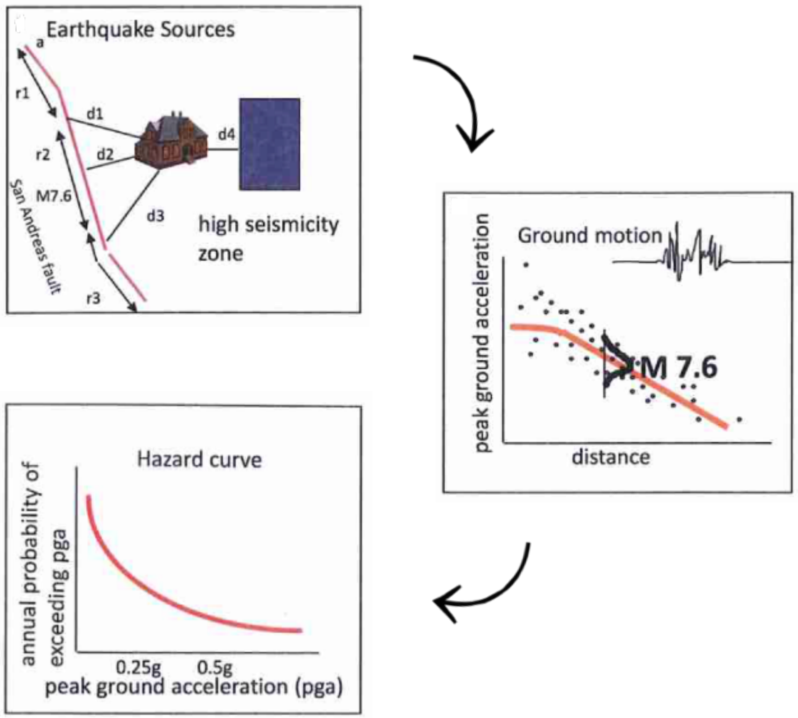
Image to Model
Location to Hazard
Analysis to Decision
seismic loads
analysis model
fragility curves
Decision Variables
- Losses
- Downtime
- Repair Cost
- Retrofit Cost
- Insurance
- etc.

Location to Hazard

Probabilistic Seismic Hazard Assessment (PSHA)



A map of active faults around a Los Angeles site (Stewart, 2014)



Basic seismic hazard methodology (from Boore et al.)

PEER PACIFIC EARTHQUAKE ENGINEERING RESEARCH CENTER

SCEC AN NSF+USGS CENTER

UCLA

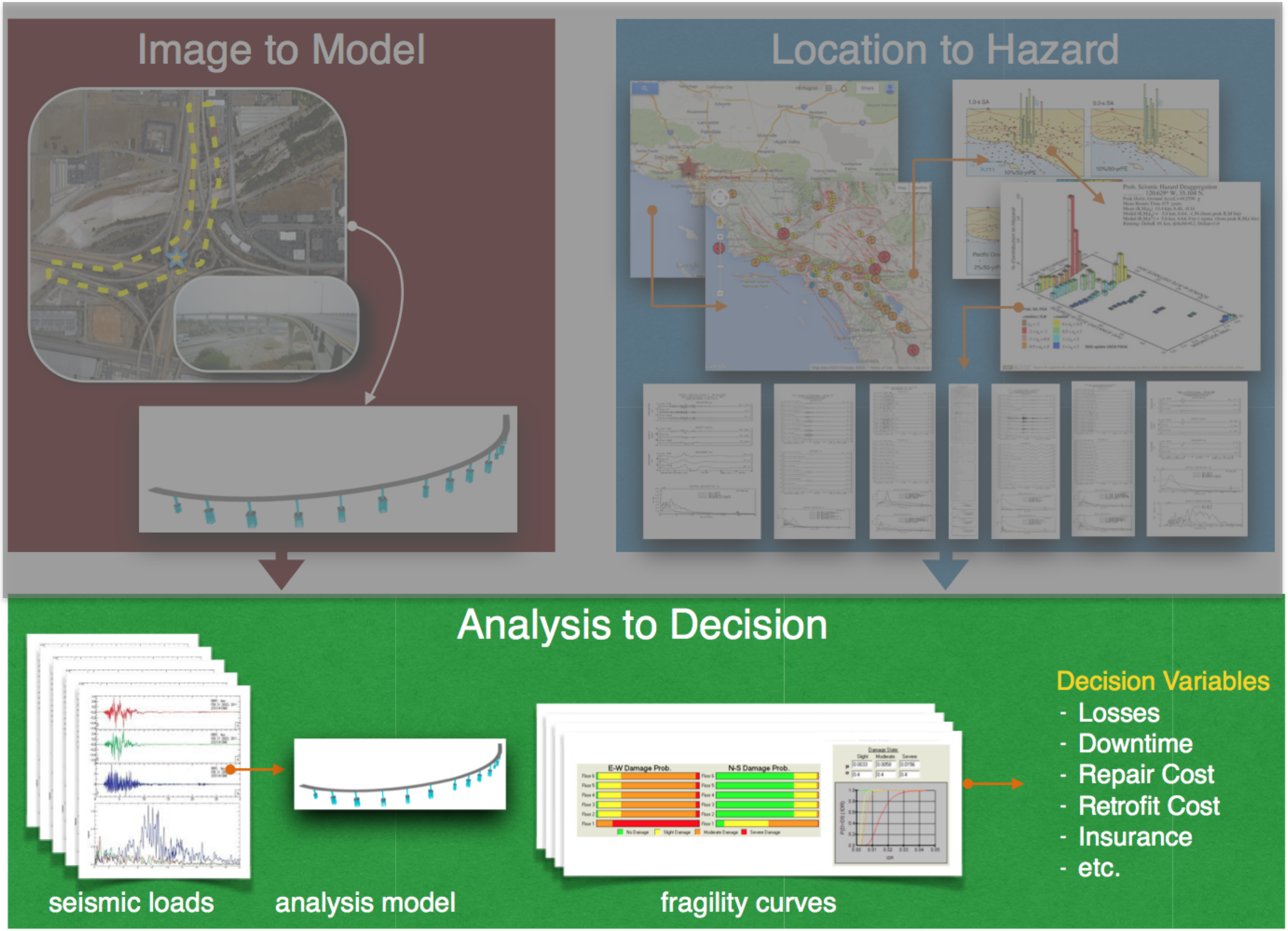
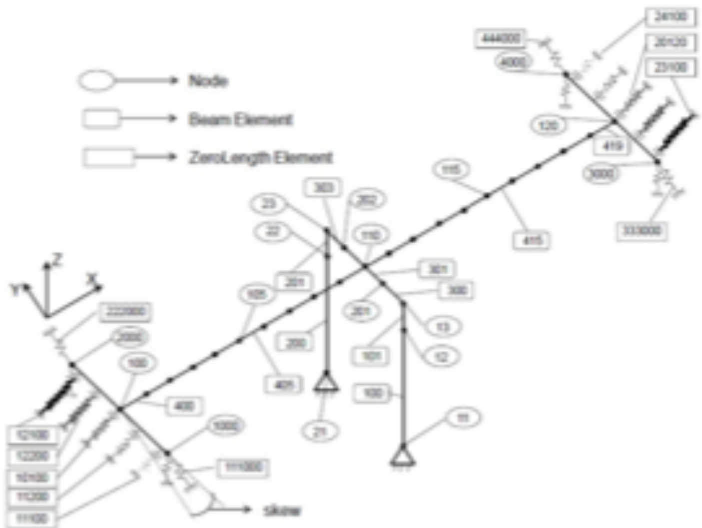


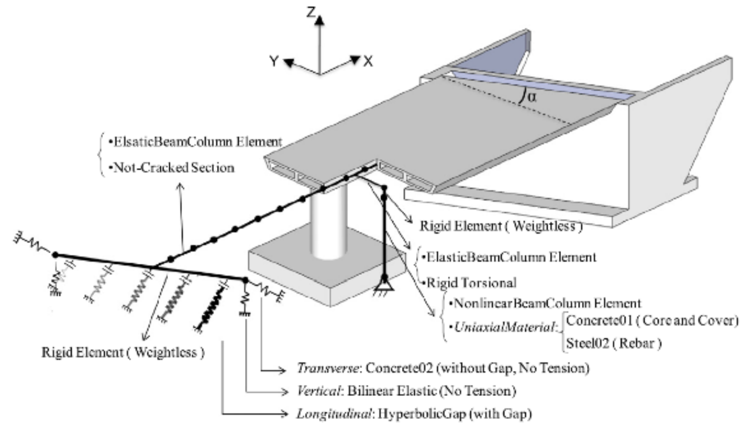
Image to Model
Location to Hazard
Analysis to Decision
Decision Variables
- Losses
- Downtime
- Repair Cost
- Retrofit Cost
- Insurance
- etc.
seismic loads
analysis model
fragility curves
E-W Damage Prob.
N-S Damage Prob.

Analysis Models

a brief overview

Building blocks of a bridge model



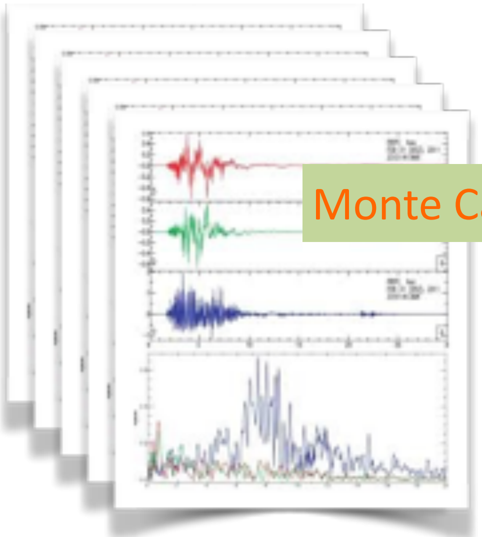


- Piles [Boulanger et al., 1999; Taciroglu et al., 2006; Khalili-Tehrani et al., 2014]
- Abutments [Stewart et al. 2007; Shamsabadi et al., 2010; Nojoumi et al., 2015]
- Shear keys [Mobasher et al., 2015; Omrani et al., 2015]
- In-span hinges [Trochalakis et al., 1997; Hube and Mosalam, 2008]
- Columns [Barry and Eberhard, 2008]
- Girders, deck (elastic)

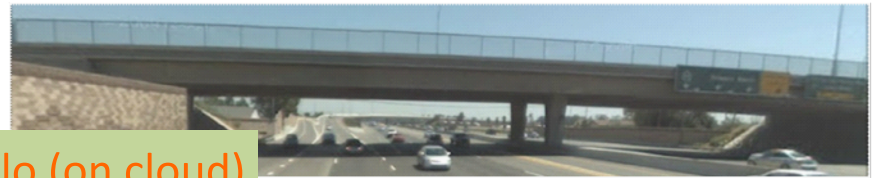
Detailed descriptions of component and system modeling are provided in

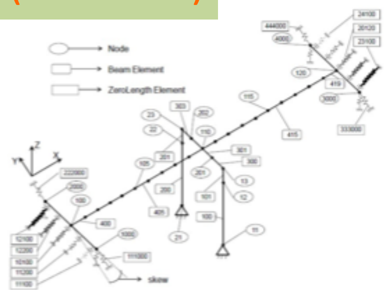
Omrani R, Mobasher B, Liang X, Gunay S, Mosalam K, Zareian F, Taciroglu E (2015). *Guidelines for Nonlinear Seismic Analysis of Ordinary Bridges: Version 2.0*, Caltrans Report No. 15-65A0454, Sacramento CA.

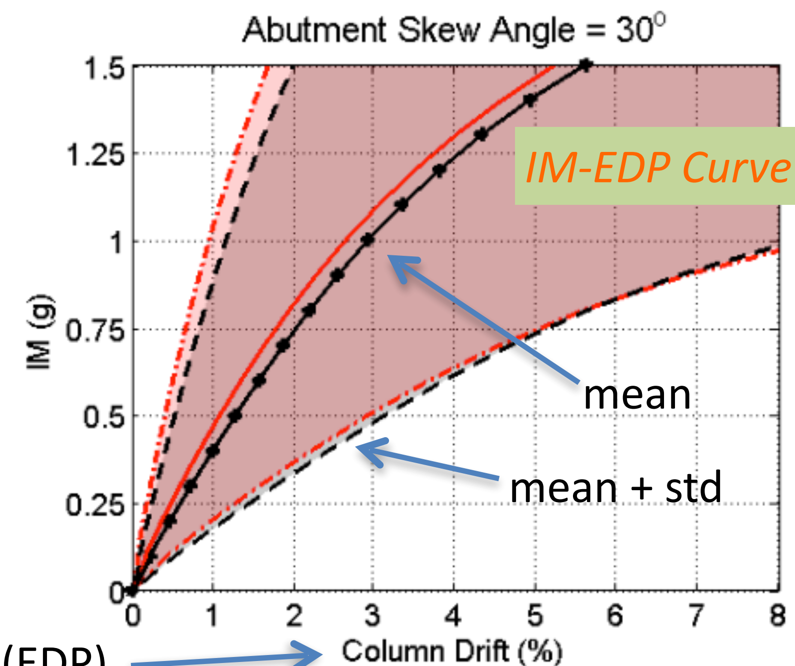
Analysis yields …



Monte Carlo (on cloud)

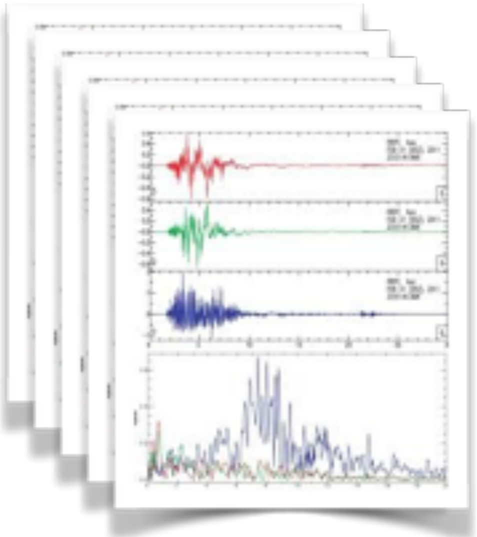


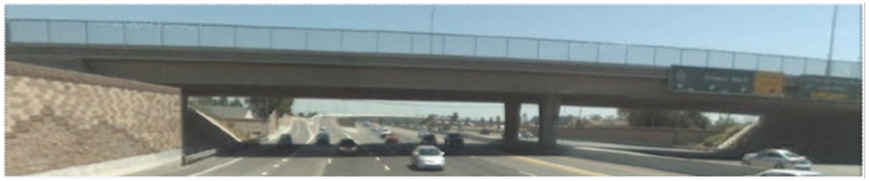


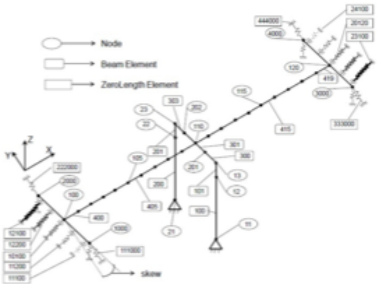


Engineering Demand Parameter (EDP)

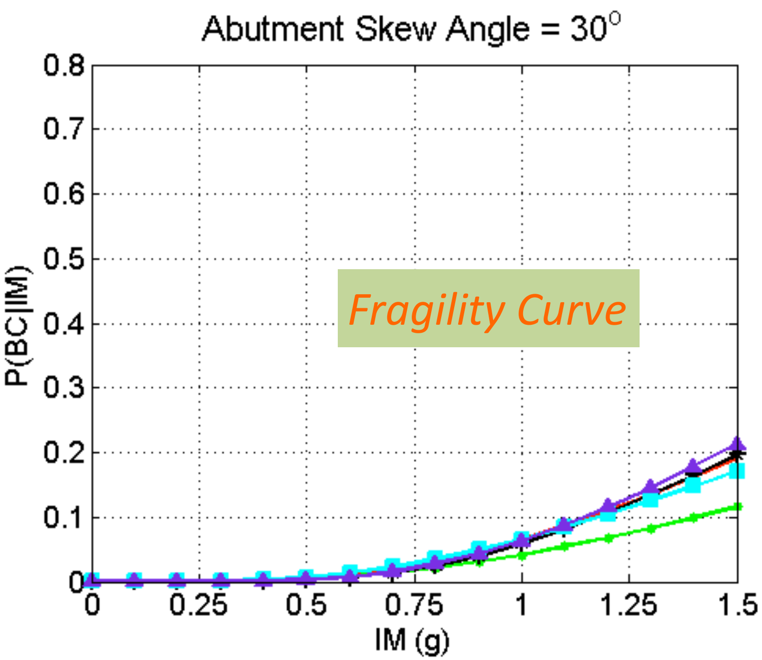
Analysis yields …







Probability of Collapse
[or *Probably of Exceedance of a pre-defined damage state for a particular component such as a shear key*]



Loss Estimation

an open problem for bridges

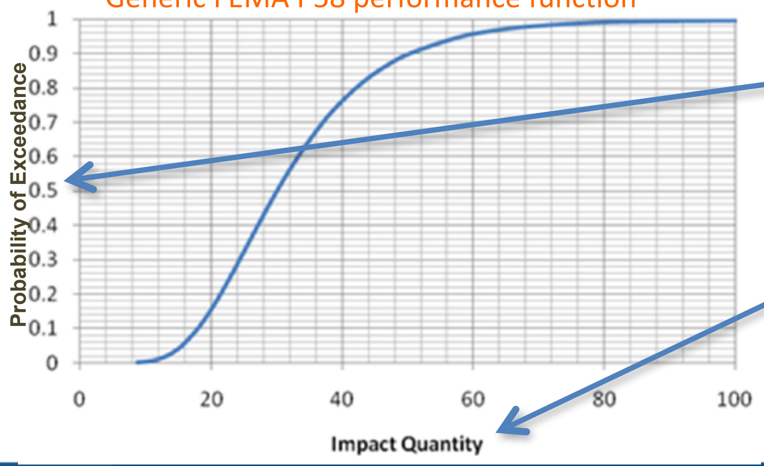
EDP or Performance State to Loss & Downtime

- Damage to a bridge leads to casualties and functional loss

Direct losses (repair cost) and indirect losses (downtime and casualties)

- Extensive research had been carried out for buildings
    - *EDP to direct and indirect Losses (e.g., Porter, 2007; Mitrani-Reiser, 2007)*
    - *Packaged into FEMA Performance Assessment Calculation Tool (PACT)*
    - *Provides fragilities/performance-functions for structural and non-structural components, and systems*

Generic FEMA P58 performance function



e.g., PoE of 2nd floor acceleration value of 0.4*g*

e.g., repair costs to MRI machine on floor 2

[other IQ examples are repair time, injuries requiring hospitalization, deaths, hours to operability, etc.

EDP or Performance State to Loss & Downtime

- Similar capabilities in loss estimation for bridges are lacking

- Our long-term plans
  - Try to replicate the FEMA-P58 methodology for bridges
    - ➢ Develop *apps (tools)* for computing component fragilities (to enable rapid post-event assessment)
    - ➢ Compile repair/downtime data and statistics (Caltrans)
  - Devise methodologies for network impact and recovery analysis (UCLA Luskin Center) >> Port of Los Angeles

A Validation Study

San Bernardino – I-10/I-215 Interchange Bridge

Coronado Bridge, San Diego CA

Validation study

San Bernardino – I-10/I-215 Interchange Bridge



Validation study

Selection of random points on the bridge by the user



Validation study

Initial processing of selected points by program



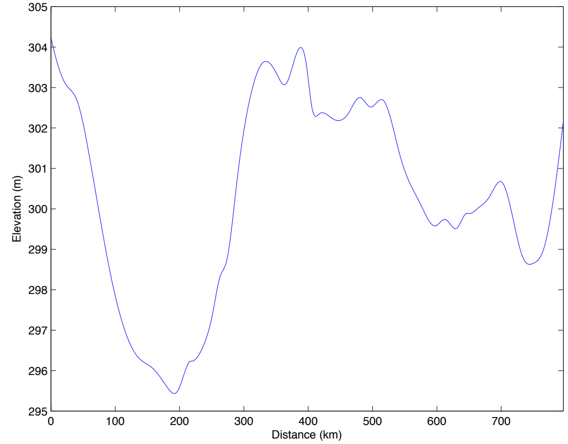
Calculation of bridge centerline curve

*Using ***UCLA*** automated image-based structural model development program through utilization of

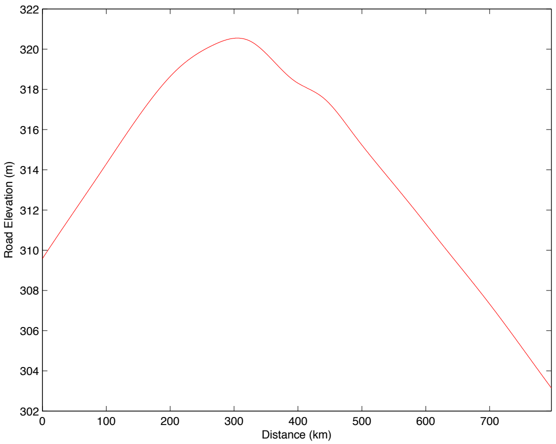
Google Maps Roads API

*Using ***UCLA*** automated image-based structural model development program through utilization of

Google Maps Elevation API



Determination of ground elevations



Determination of road elevations

*Using ***UCLA*** automated image-based structural model development program through utilization of

MapQuest Directions API

Validation study

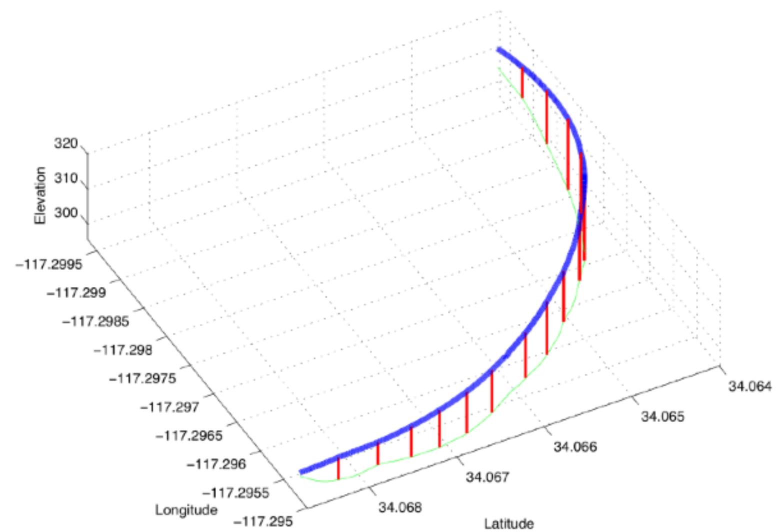
Image processing to identify bent locations and developing the wireframe model



Identification of bent locations

*Using ***UCLA*** automated image-based structural model development program via *Image Analyzer Module*

*Using ***UCLA*** automated image-based structural model development program via *Wireframe Model Builder Module*



Establishing of wireframe model

Validation study

Image processing to identify in-span hinge locations

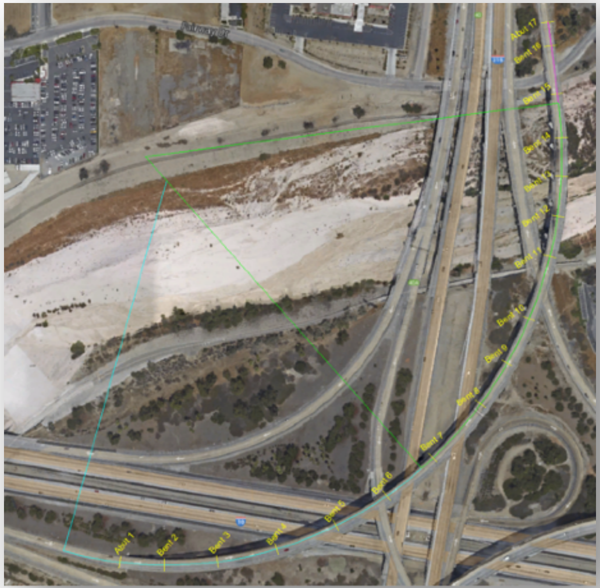


Identification of in-span hinge locations

*Using ***UCLA*** automated image-based structural model development program via *Image Analyzer Module*

Validation study

Using of auxiliary data to determine superelevation profile*



Determination of curve superelevation at each sampling point

Using ***UCLA* automated image-based structural model development program via *Image Analyzer Module*

Identify centerline geometry in terms of constituent curves/spirals.

↓

Get bridge speed limit data through Google Roads API.

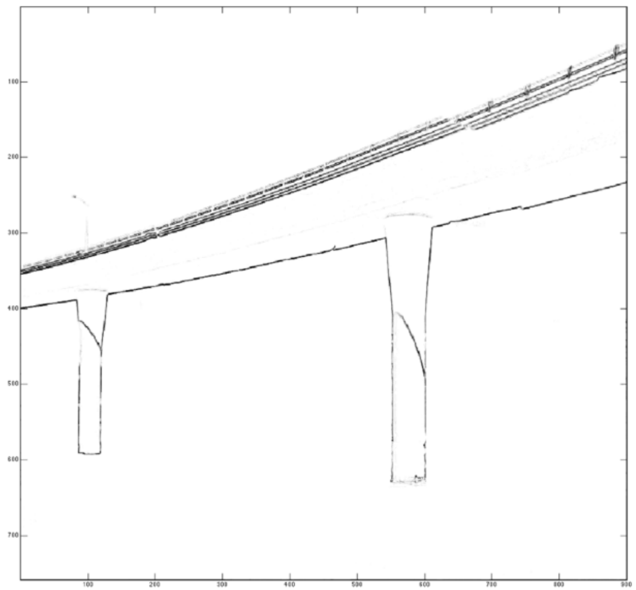
↓

Estimate curve superelevation at each sampling point.

Basic methodology to determine curve superelevation profile

Validation study

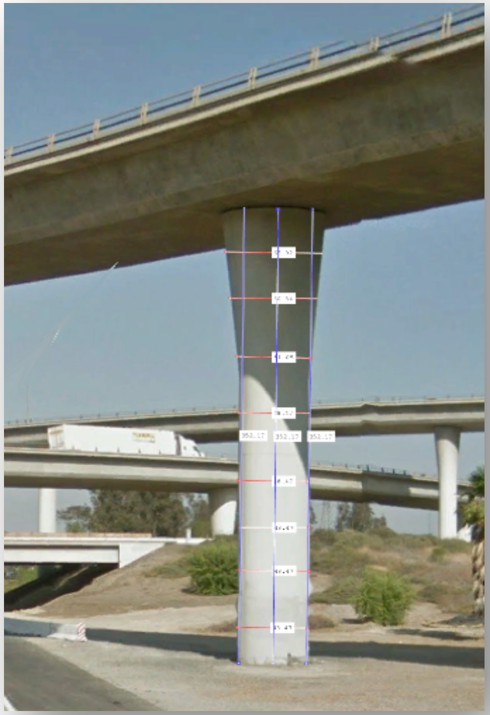
Determination of bridge column dimensions



Detection of column edges

*Using ***UCLA*** automated image-based structural model development program via *Fuzzy Logic Edge Detection Module*

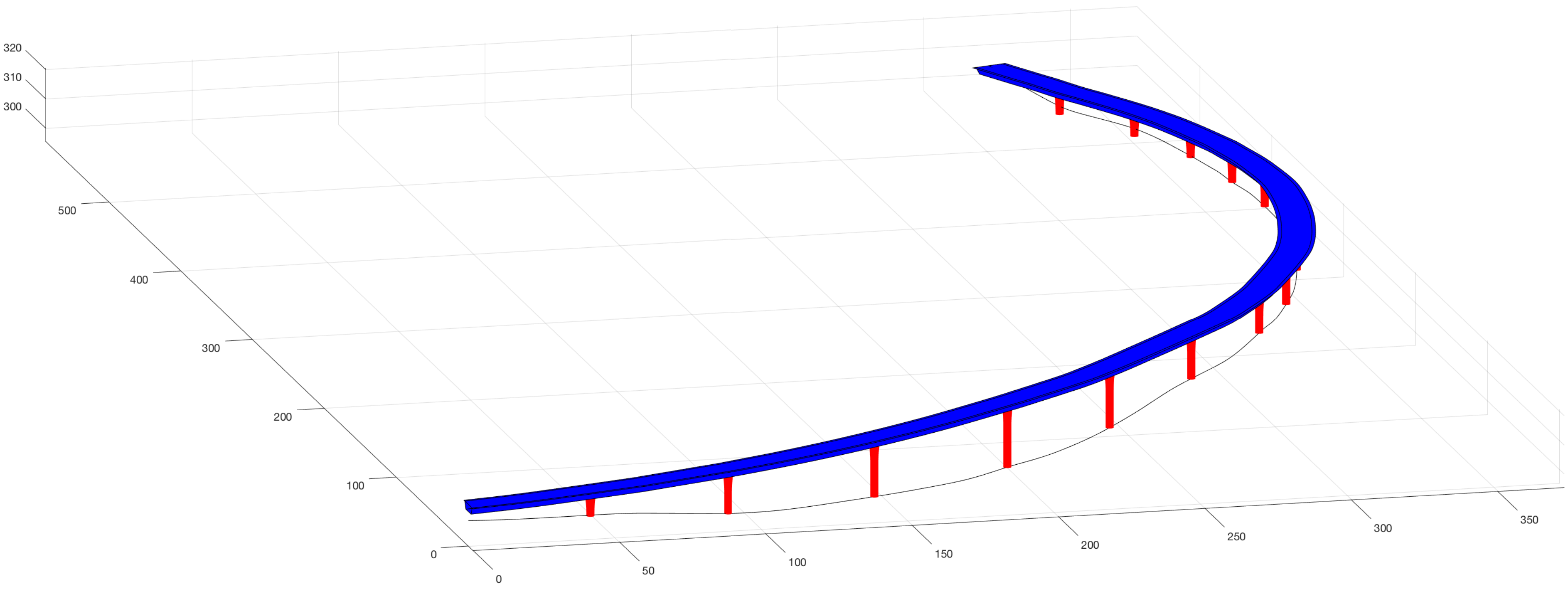
*Using ***UCLA*** automated image-based structural model development program via *Pixel Counter Module*



Determination of column dimensions

Validation study

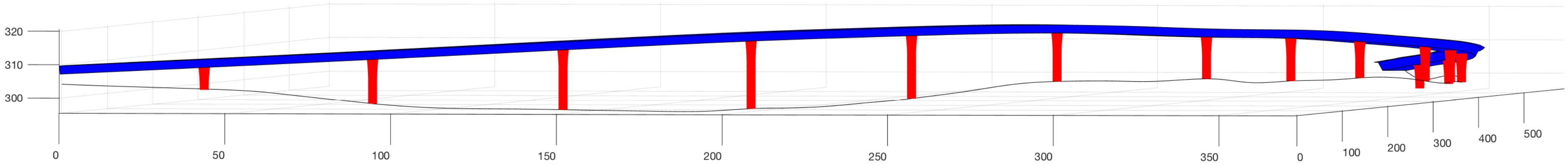
Resulting model



Validation study

Resulting model





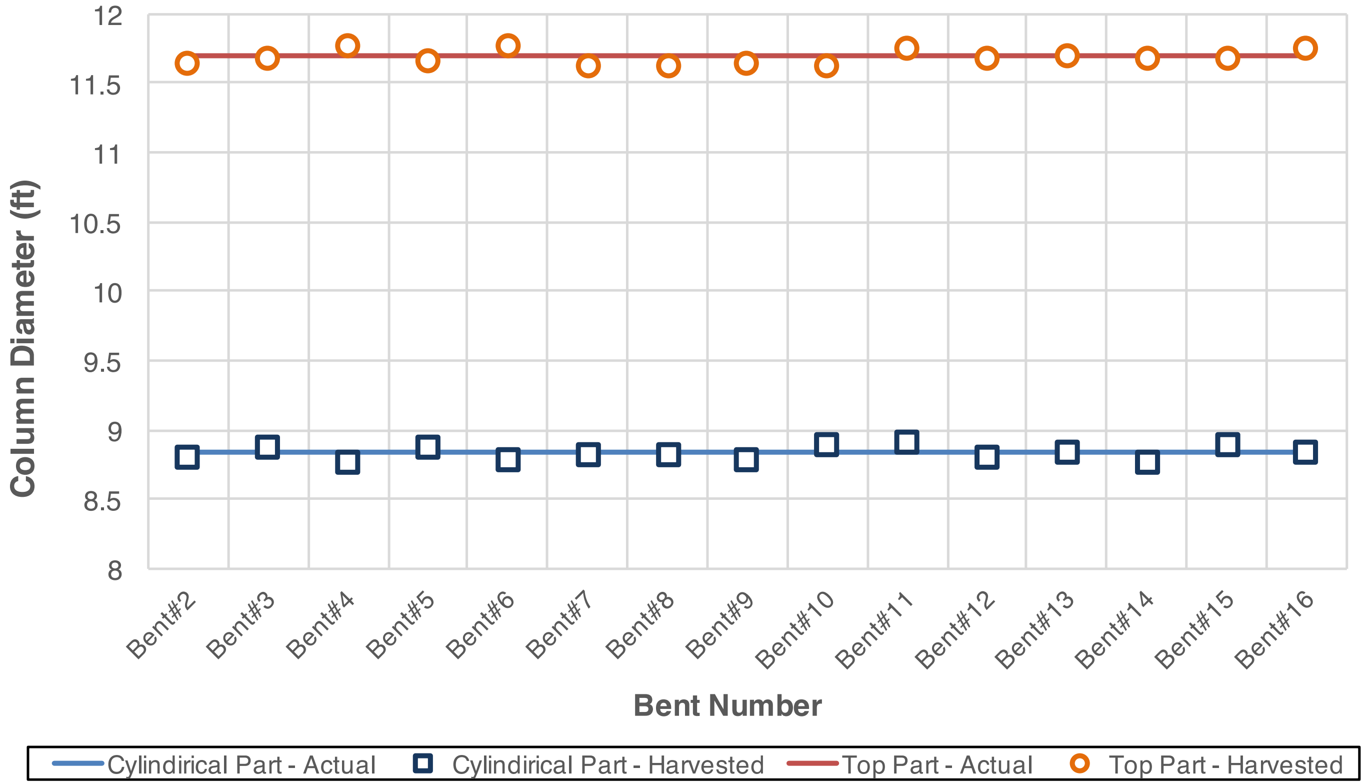
Validation study

harvested data vs. as-built: bridge deck elevation



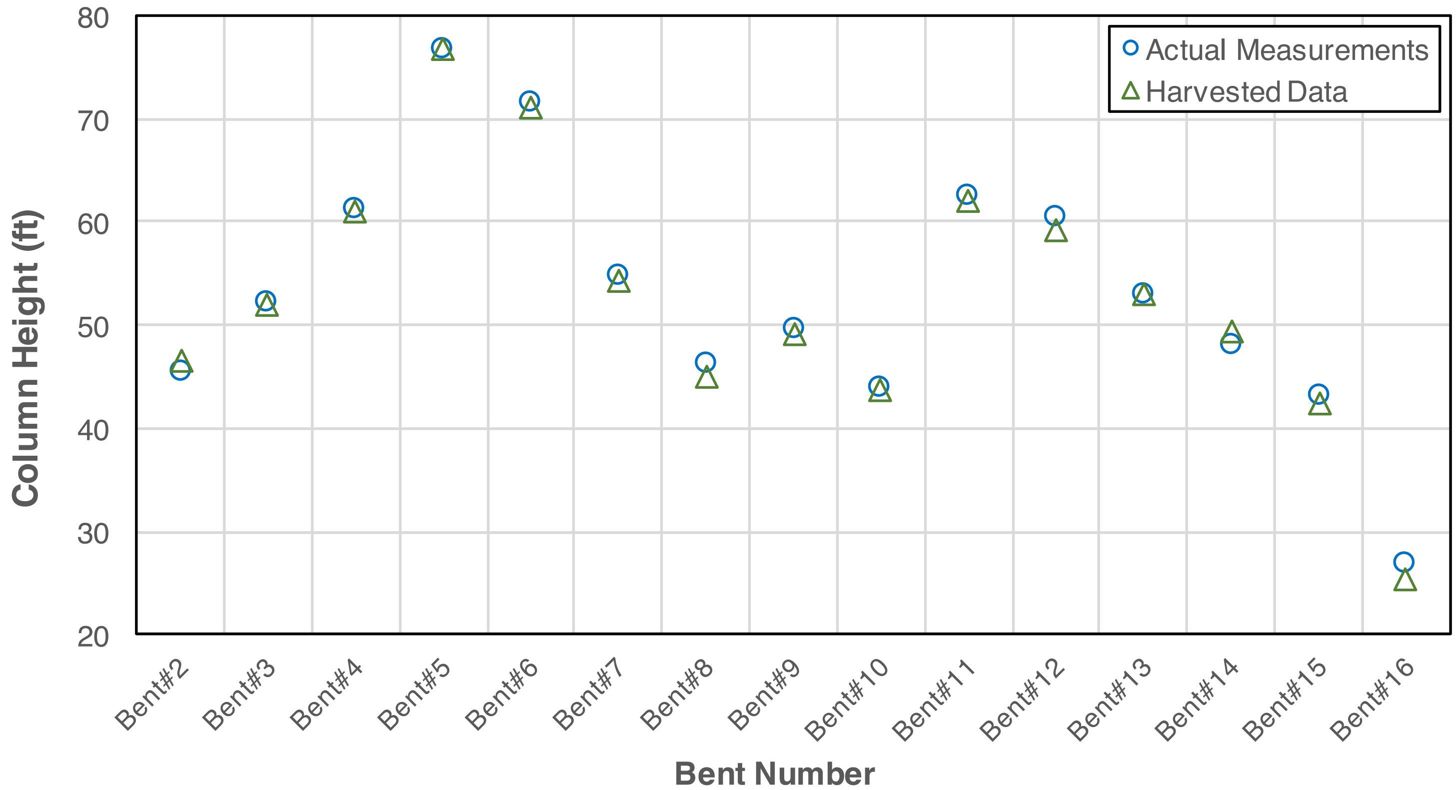
Validation study

harvested data vs. as-built: column diameters



Validation study

harvested data vs. as-built: column heights



Validation study

harvested data vs. as-built: modal periods

	$T_{Image\text{-}Based}$ (sec)	$T_{As\text{-}Built}$ (sec)
Mode 1	1.357	1.528
Mode 2	1.182	1.294
Mode 3	1.028	1.091
Mode 4	0.947	1.019
Mode 5	0.892	0.942
Mode 6	0.836	0.881
Mode 7	0.784	0.807
Mode 8	0.746	0.788

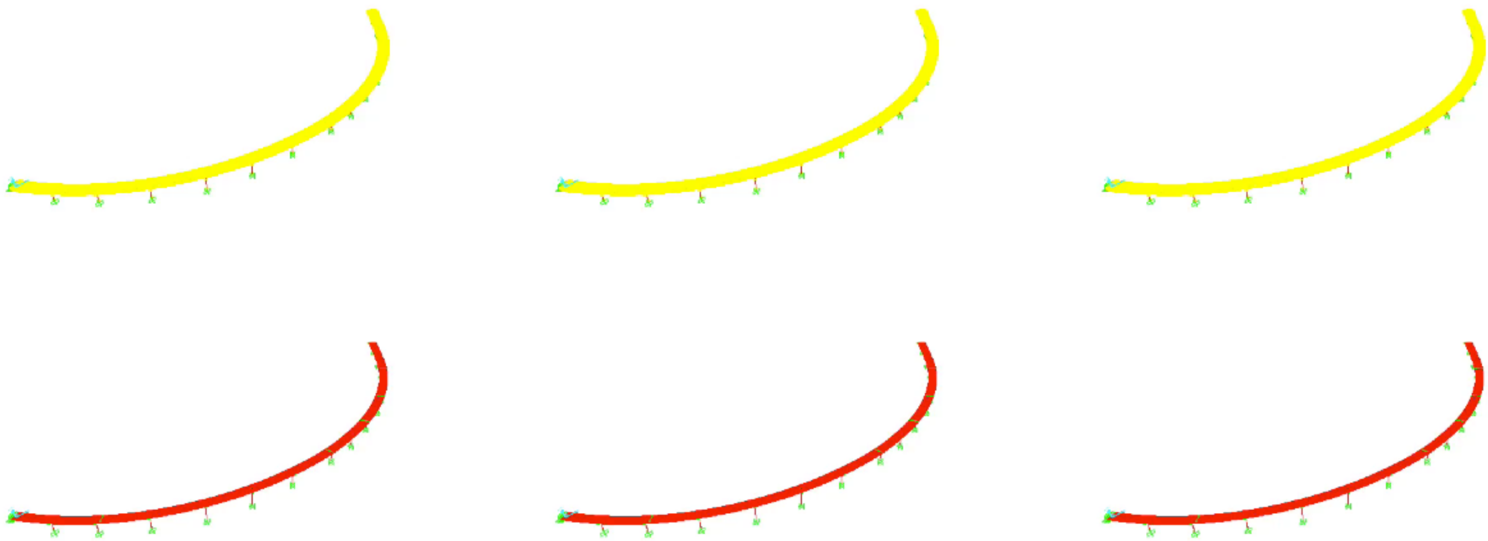
Validation study

harvested data vs. as-built: mode shapes

Mode 1 | Mode 2 | Mode 3

Image-Based

As-Built



Sample Applications

Coronado Bridge, San Diego CA

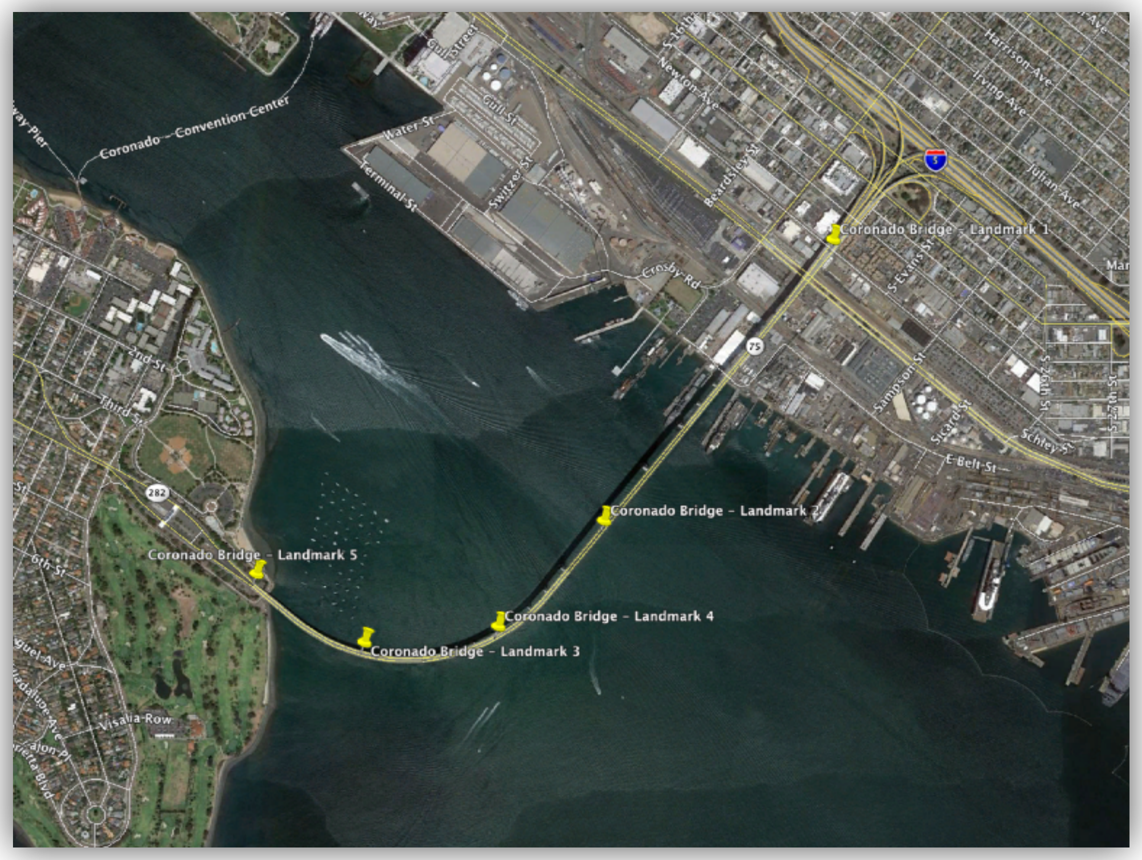
Wilshire Blvd/I-405N On-Ramp, Los Angeles, CA

Sample Application: San Diego – Coronado Bridge



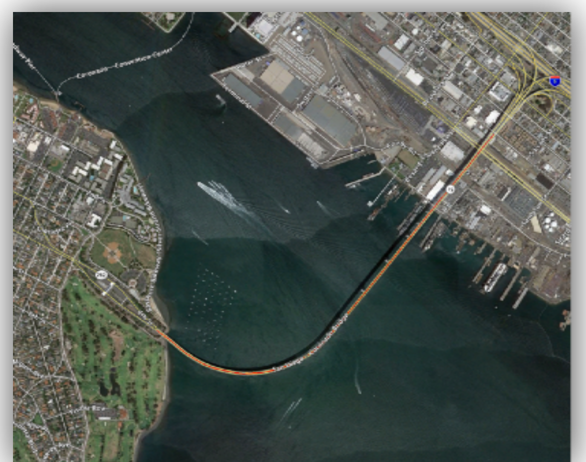
Sample Application: San Diego – Coronado Bridge

Selection of points along the bridge by the user



Sample Application: San Diego – Coronado Bridge

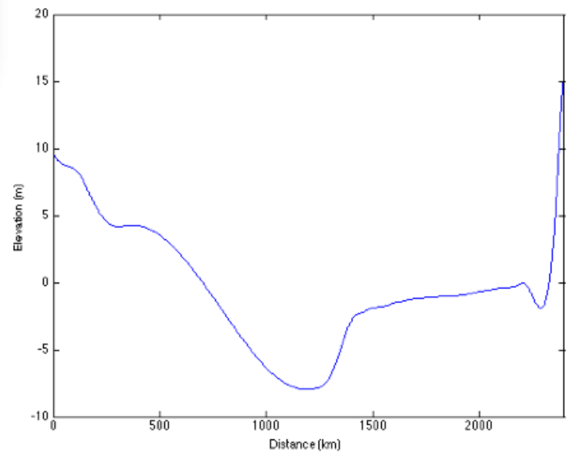
Initial processing of selected points by program



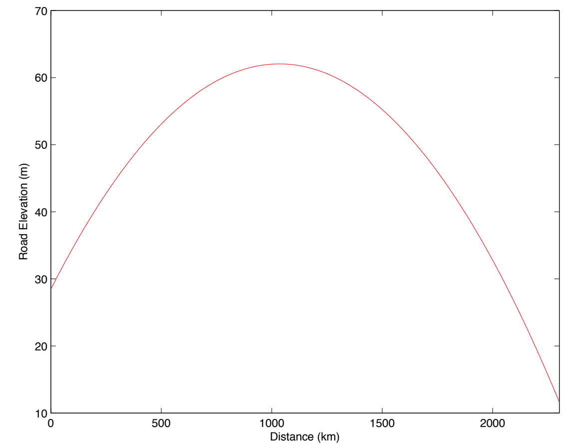
Calculation of bridge centerline curve

*Using ***UCLA*** automated image-based structural model development code

*Using ***UCLA*** automated image-based structural model development code



Determination of ground elevations

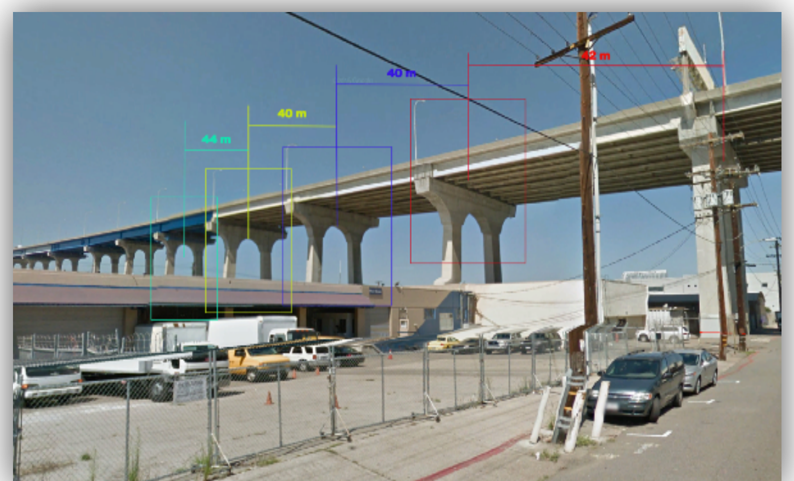


Determination of road elevations

*Using ***UCLA*** automated image-based structural model development code

Sample Application: San Diego – Coronado Bridge

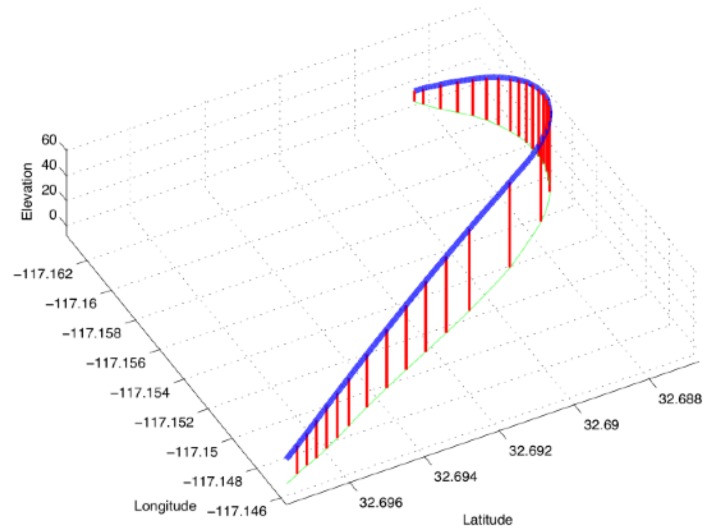
Using image processing to identify bent locations and developing the wireframe model



Identification of bent locations

*Using ***UCLA*** automated image-based structural model development program via *Image Analyzer Module*

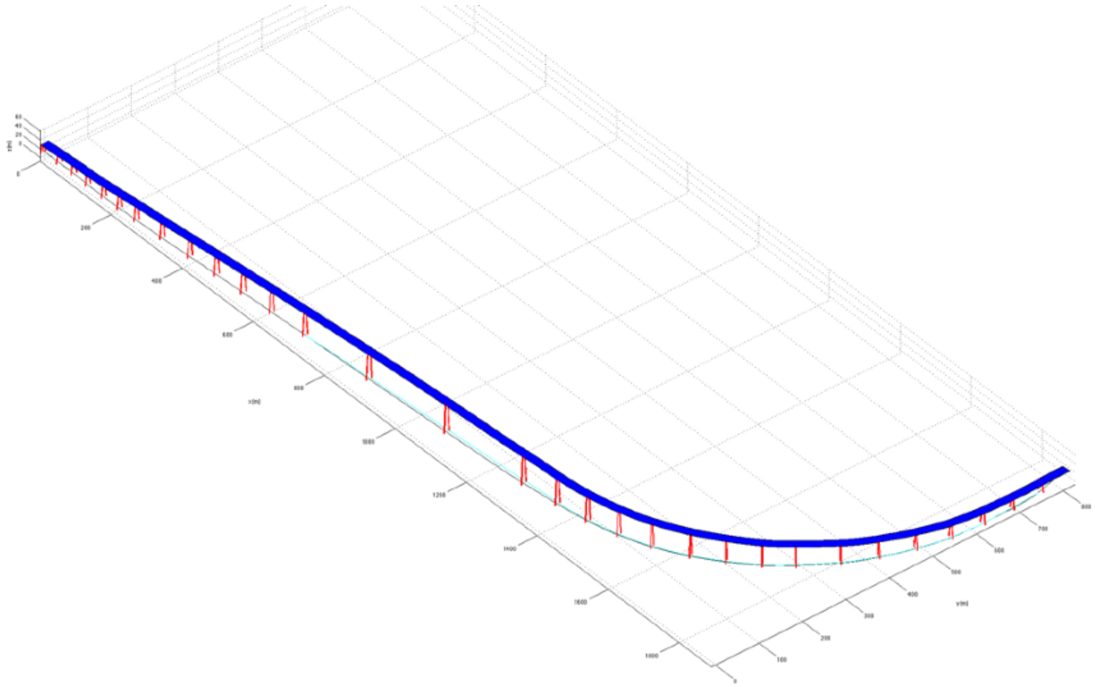
*Using ***UCLA*** automated image-based structural model development program via *Wireframe Model Builder Module*



Establishing the preliminary wireframe model

Sample Application: San Diego – Coronado Bridge

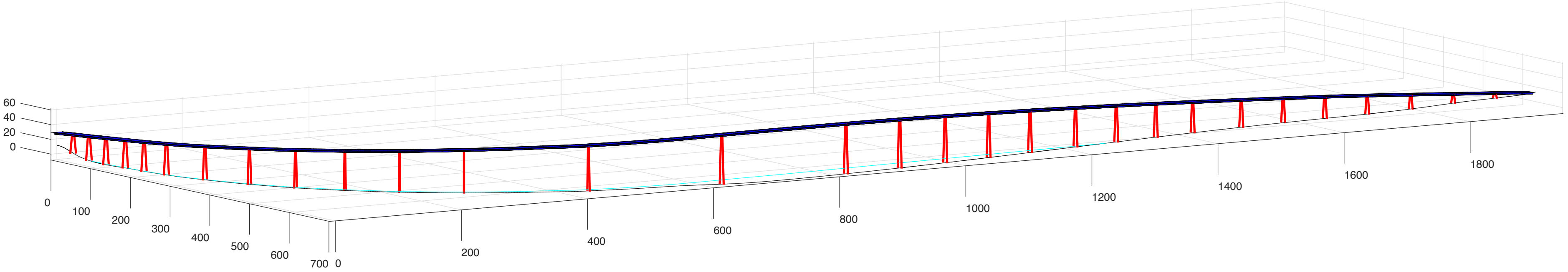
Using image processing to identify bent locations and developing the wireframe model



Final wireframe model

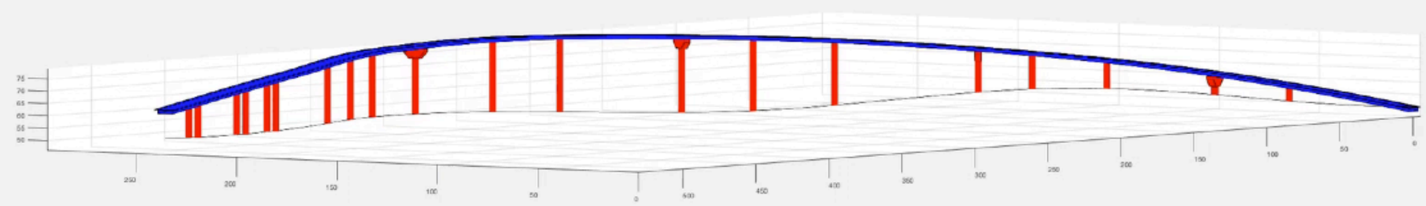
Sample Application: Coronado Bridge, San Diego





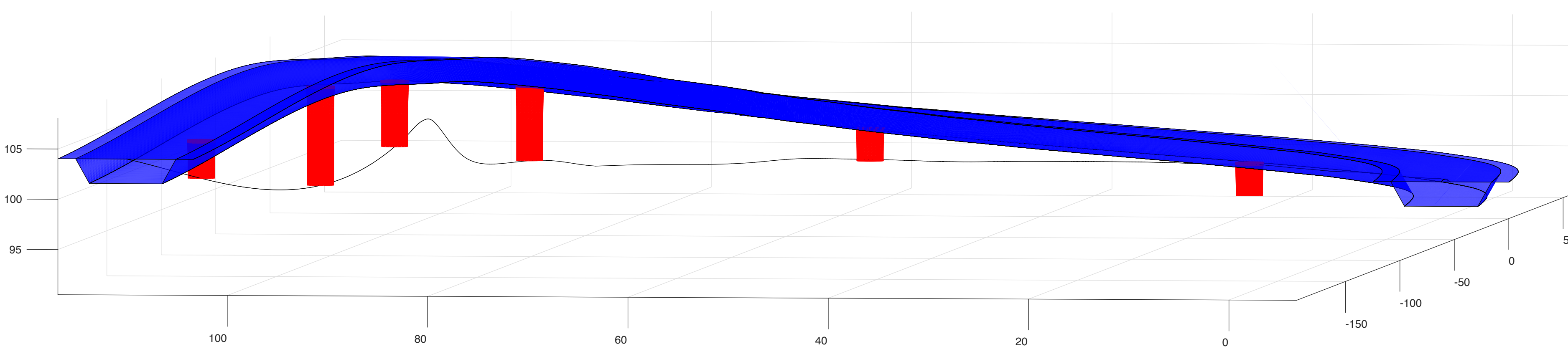
Sample Application: LA I10/I405N Interchange





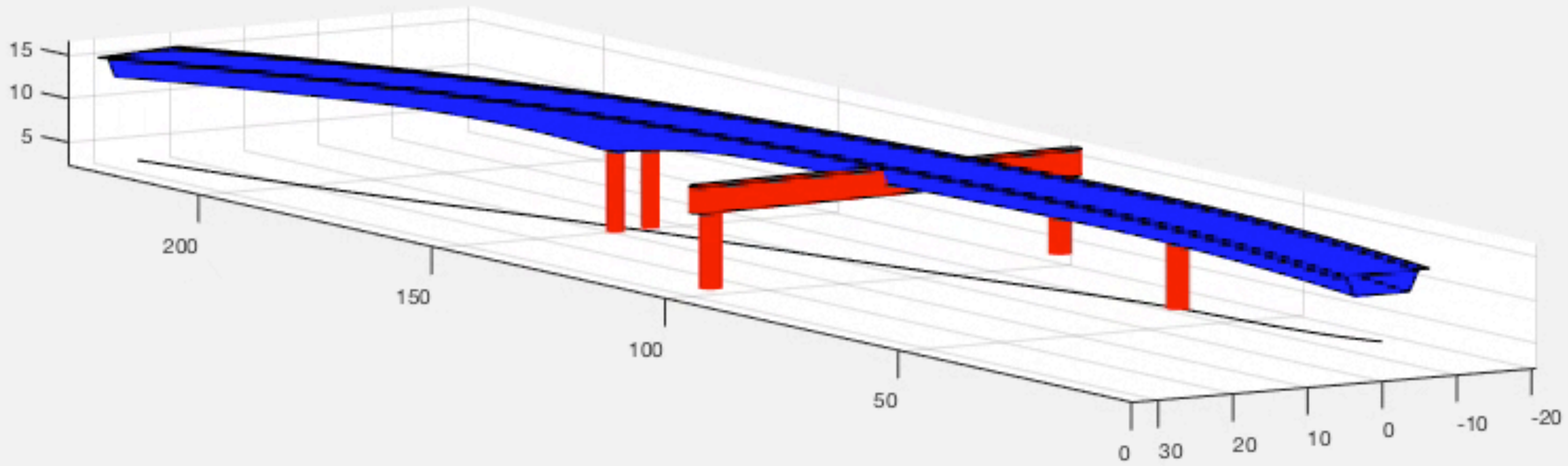
Sample Application: LA Wilshire/I-405N On-Ramp





Sample Application: LA I405N/CA22W Interchange



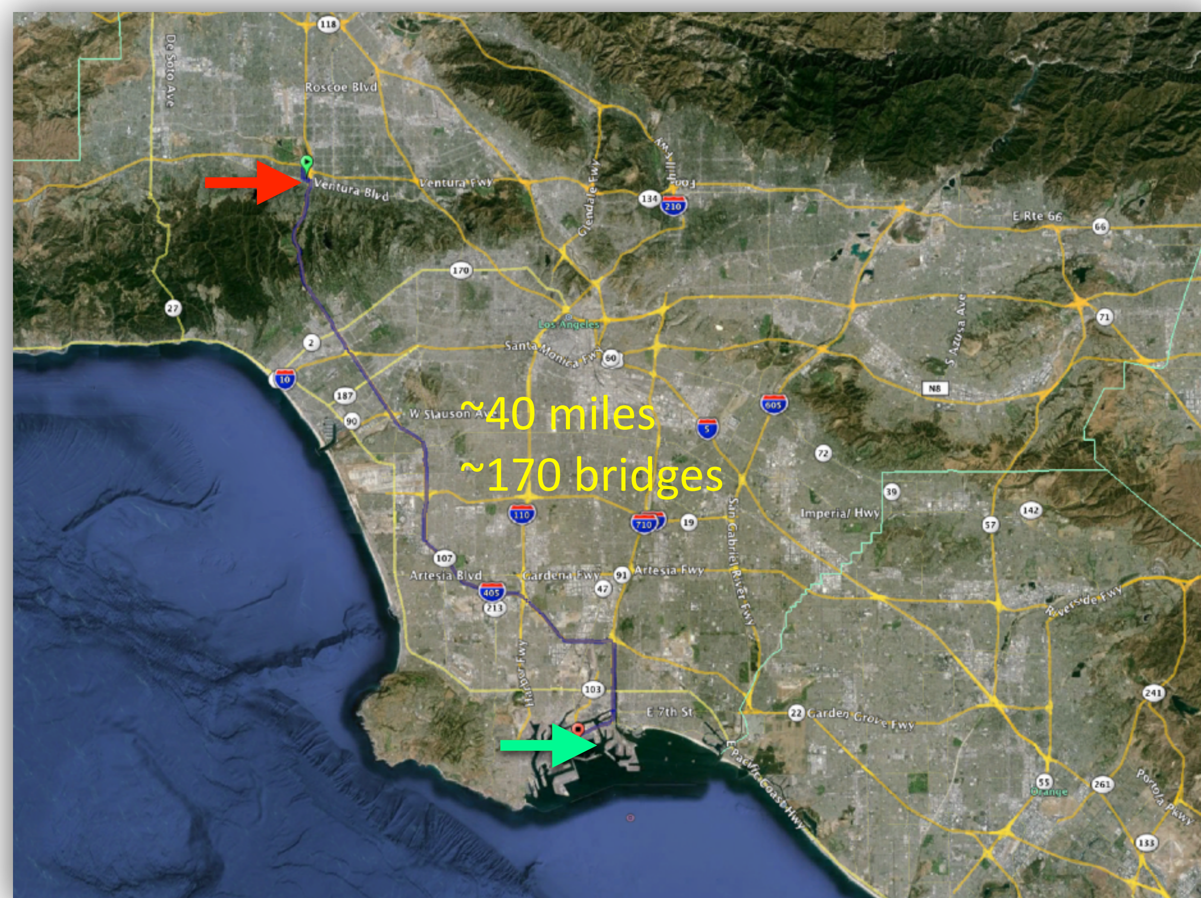


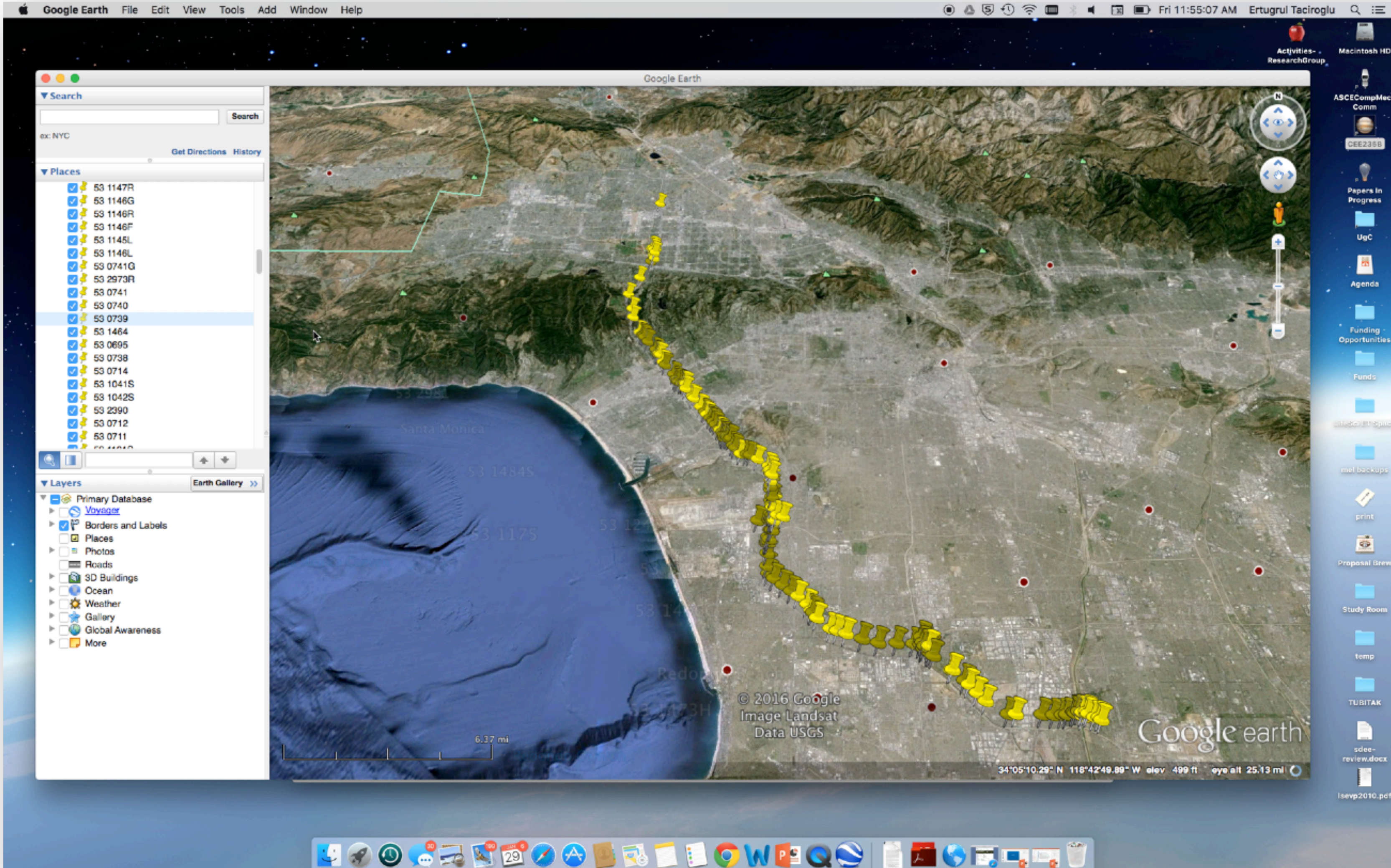
Testbed Route

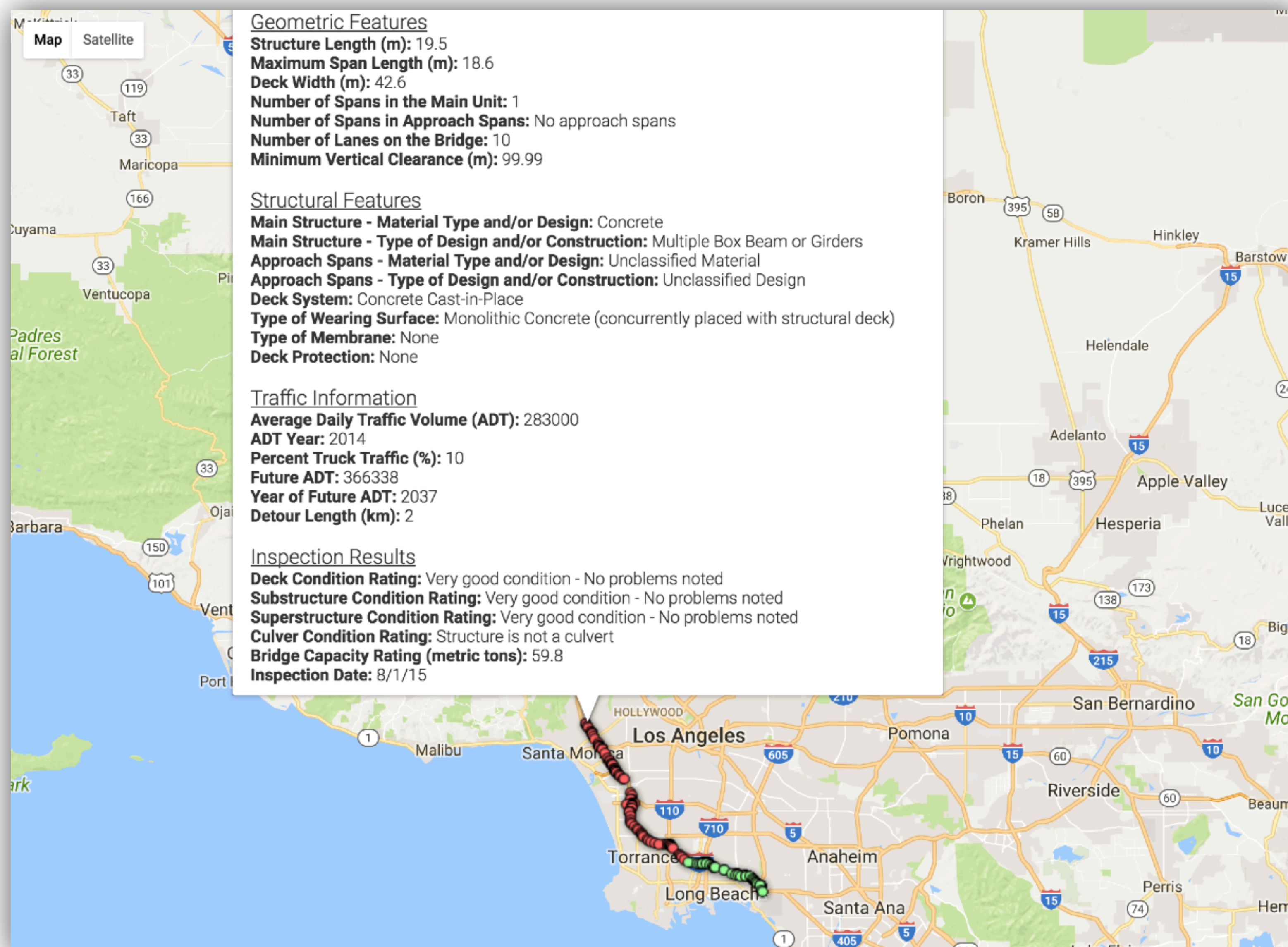
US-101/I-405 Interchange to Port of Los Angeles

Regional assessment

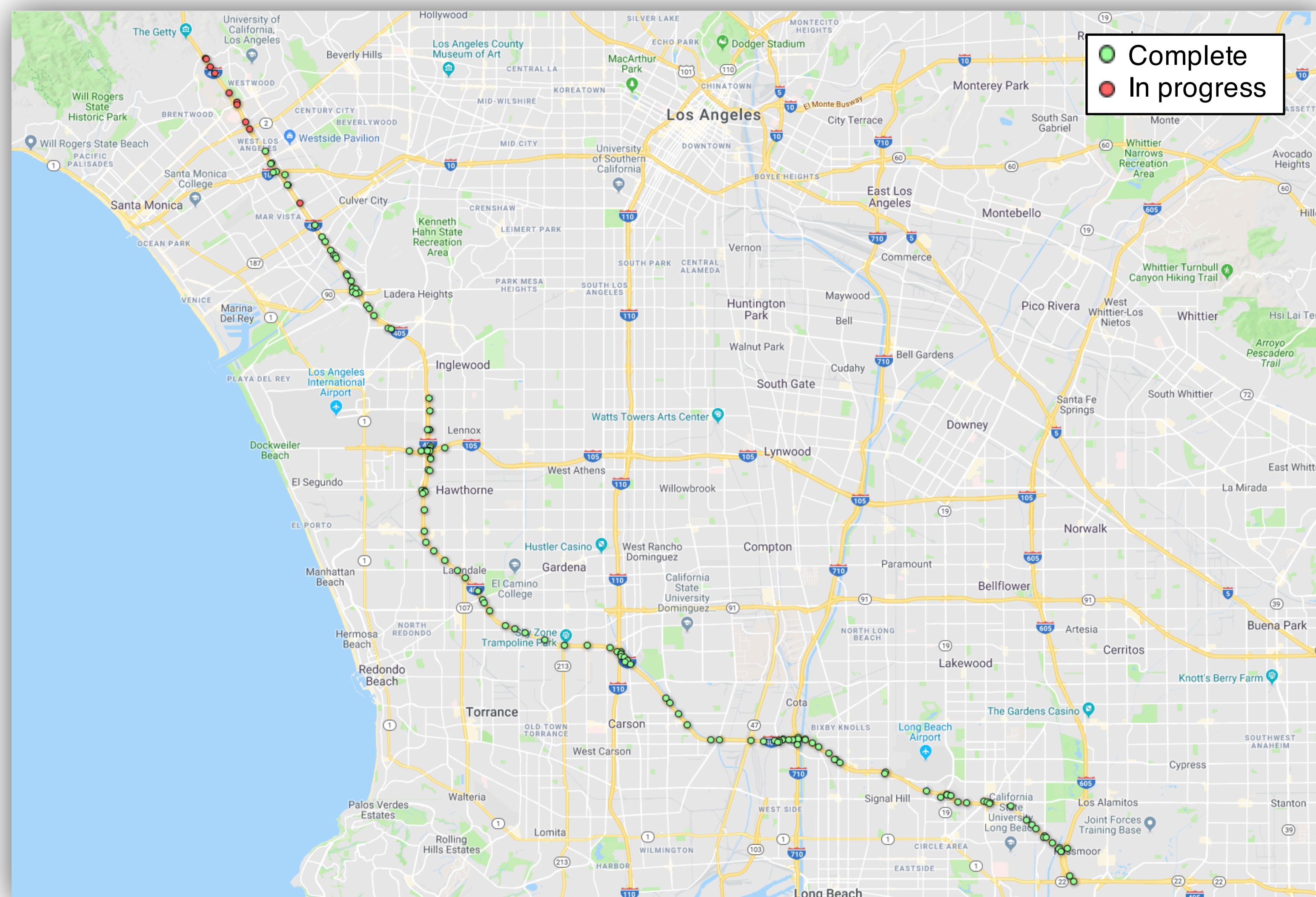
US-101/I-405 Interchange to Port of Los Angeles



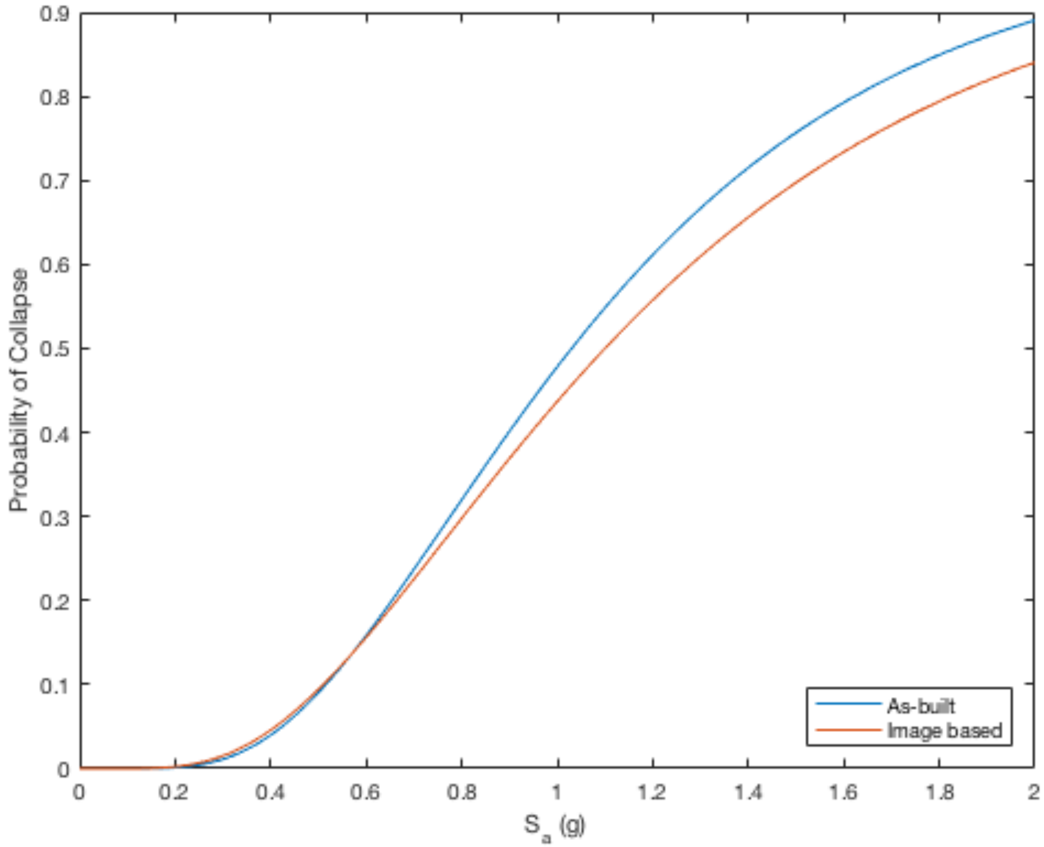




Map
Satellite
Geometric Features
Structure Length (m): 19.5
Maximum Span Length (m): 18.6
Deck Width (m): 42.6
Number of Spans in the Main Unit: 1
Number of Spans in Approach Spans: No approach spans
Number of Lanes on the Bridge: 10
Minimum Vertical Clearance (m): 99.99
Structural Features
Main Structure - Material Type and/or Design: Concrete
Main Structure - Type of Design and/or Construction: Multiple Box Beam or Girders
Approach Spans - Material Type and/or Design: Unclassified Material
Approach Spans - Type of Design and/or Construction: Unclassified Design
Deck System: Concrete Cast-in-Place
Type of Wearing Surface: Monolithic Concrete (concurrently placed with structural deck)
Type of Membrane: None
Deck Protection: None
Traffic Information
Average Daily Traffic Volume (ADT): 283000
ADT Year: 2014
Percent Truck Traffic (%): 10
Future ADT: 366338
Year of Future ADT: 2037
Detour Length (km): 2
Inspection Results
Deck Condition Rating: Very good condition - No problems noted
Substructure Condition Rating: Very good condition - No problems noted
Superstructure Condition Rating: Very good condition - No problems noted
Culver Condition Rating: Structure is not a culvert
Bridge Capacity Rating (metric tons): 59.8
Inspection Date: 8/1/15
Taft
Maricopa
Ventucopa
Boron
Kramer Hills
Hinkley
Barstow
Helendale
Adelanto
Apple Valley
Phelan
Hesperia
San Bernardino
Los Angeles
Pomona
Malibu
Riverside
Torrance
Anaheim
Long Beach
Santa Ana
Perris
Lake Elsinore


Complete
In progress

Harvested data vs. as-built: fragility curves (collapse)



Regional Assessment Application Example

Port of Los Angeles

Region of Interest

Port of Los Angeles

- 5x6 miles rectangular region containing all critical bridges connecting to Port of Los Angeles
- ROI contains 95 bridges
- 62 bridges built <1970 and have not been retrofitted

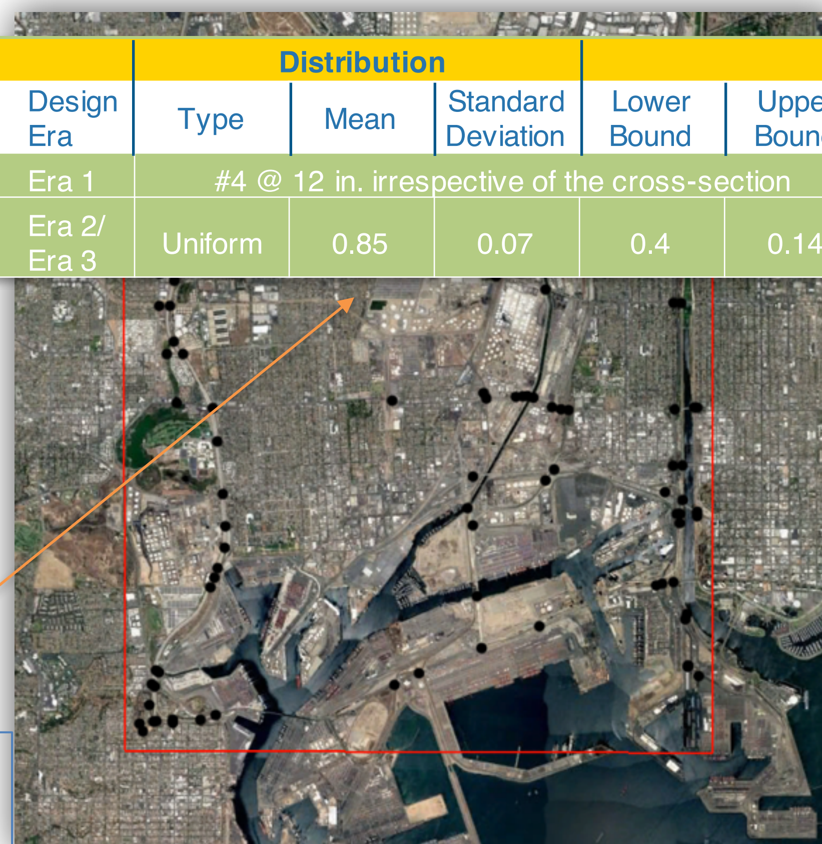


Bridge Model Inventory

- Geometries generated with UCLA tool from street view + satellite images
- Structural properties are assigned probabilistically based on a Georgia Tech study of California bridges (Mangalathu, 2017)
- The study contains statistical distributions for
  - Concrete compressive strength*
  - Steel yield strength*
  - Longitudinal steel reinforcement ratio
  - Transverse steel reinforcement ratio*
  - Foundation translation and rotational stiffness*
  - Damping
  - Mass factor

mean values here

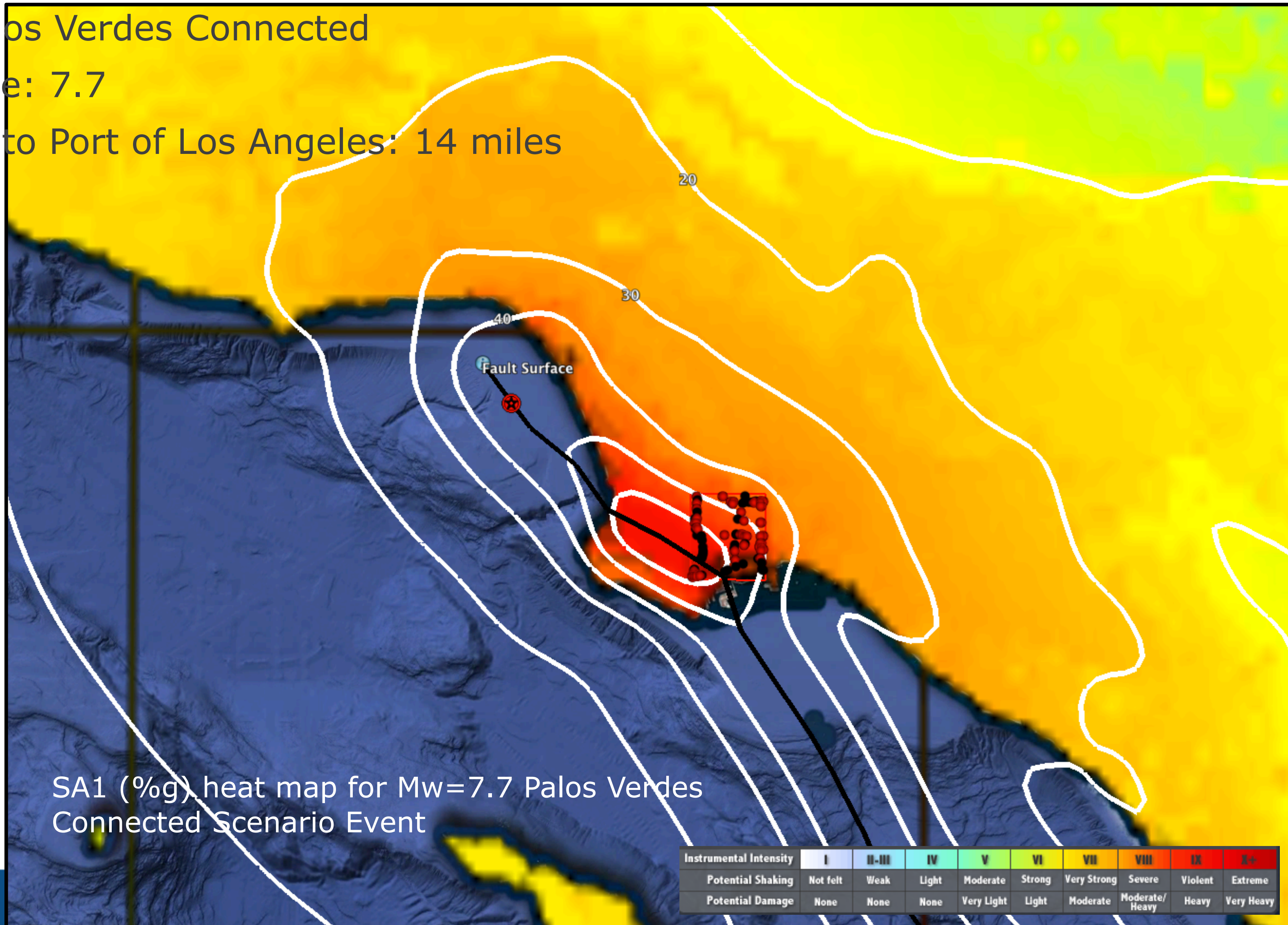
	Distribution				
Design Era	Type	Mean	Standard Deviation	Lower Bound	Upper Bound
Era 1	#4 @ 12 in. irrespective of the cross-section				
Era 2/ Era 3	Uniform	0.85	0.07	0.4	0.14



* Depends on design era (Era 1: pre-1971/pre-ductile, Era 2: 1971-1990/early ductile, Era 3: post-1990/modern ductile

Scenario Event

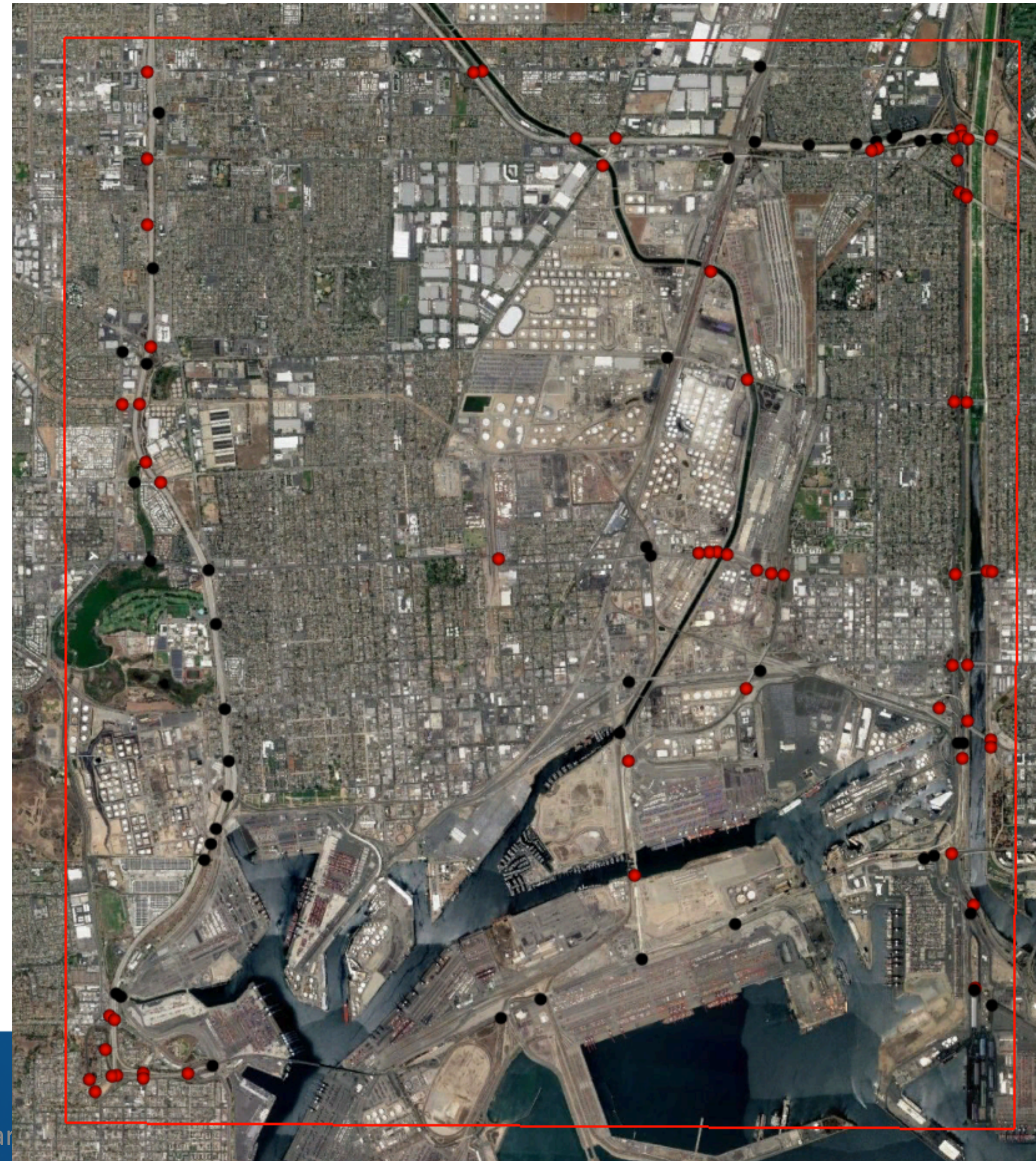
- Fault: Palos Verdes Connected
- Magnitude: 7.7
- Distance to Port of Los Angeles: 14 miles



SA1 (%g) heat map for Mw=7.7 Palos Verdes Connected Scenario Event

Bridge Closures

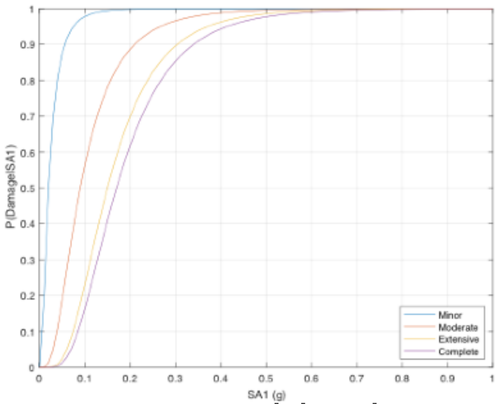
- Bridges with functionality <20% assumed closed
- Number of bridges closed
  - After 7 days: 53 bridges
  - After 120 days: 42 bridges



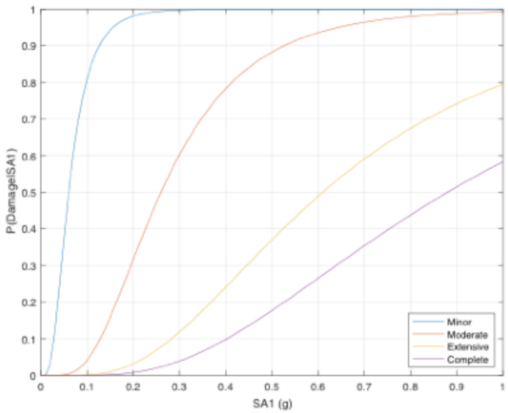
UCLA

Bridge Closures

3-span bridge
YB=1970, seat abutment



5-span curved bridge
YB=1997, seat abutment



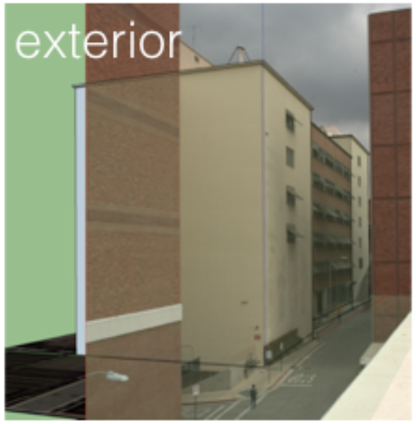


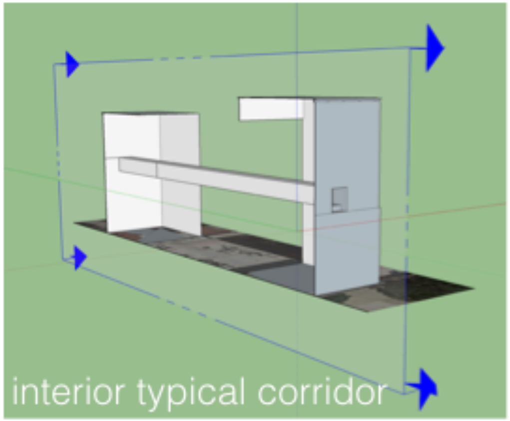
Quo Vadis?

- Further develop Image to Model Capabilities
- Develop user-interface (a GIS-integrated web site)
- Combine bridge closure data with traffic congestion simulation and estimate economic losses (USC collaboration)
- Expand to Region of Interest
- Consider realistic aftershock effects

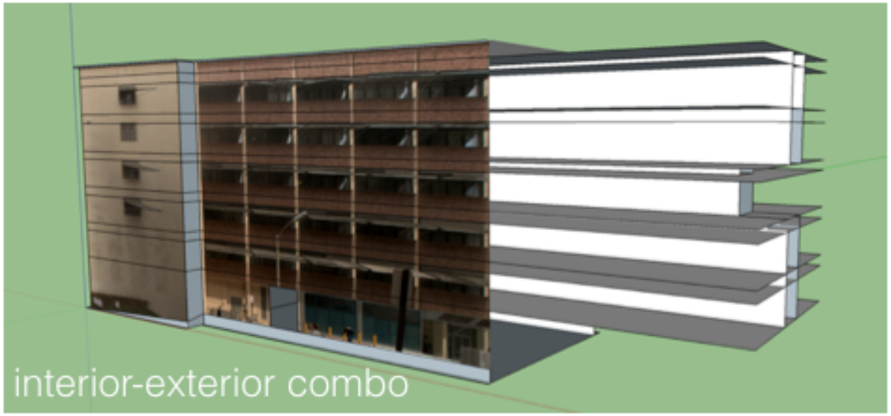
What about buildings?

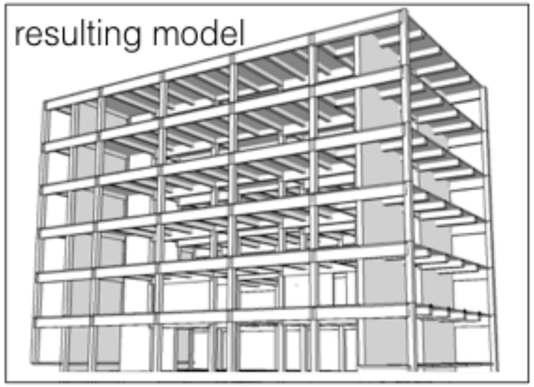
Building models from image data



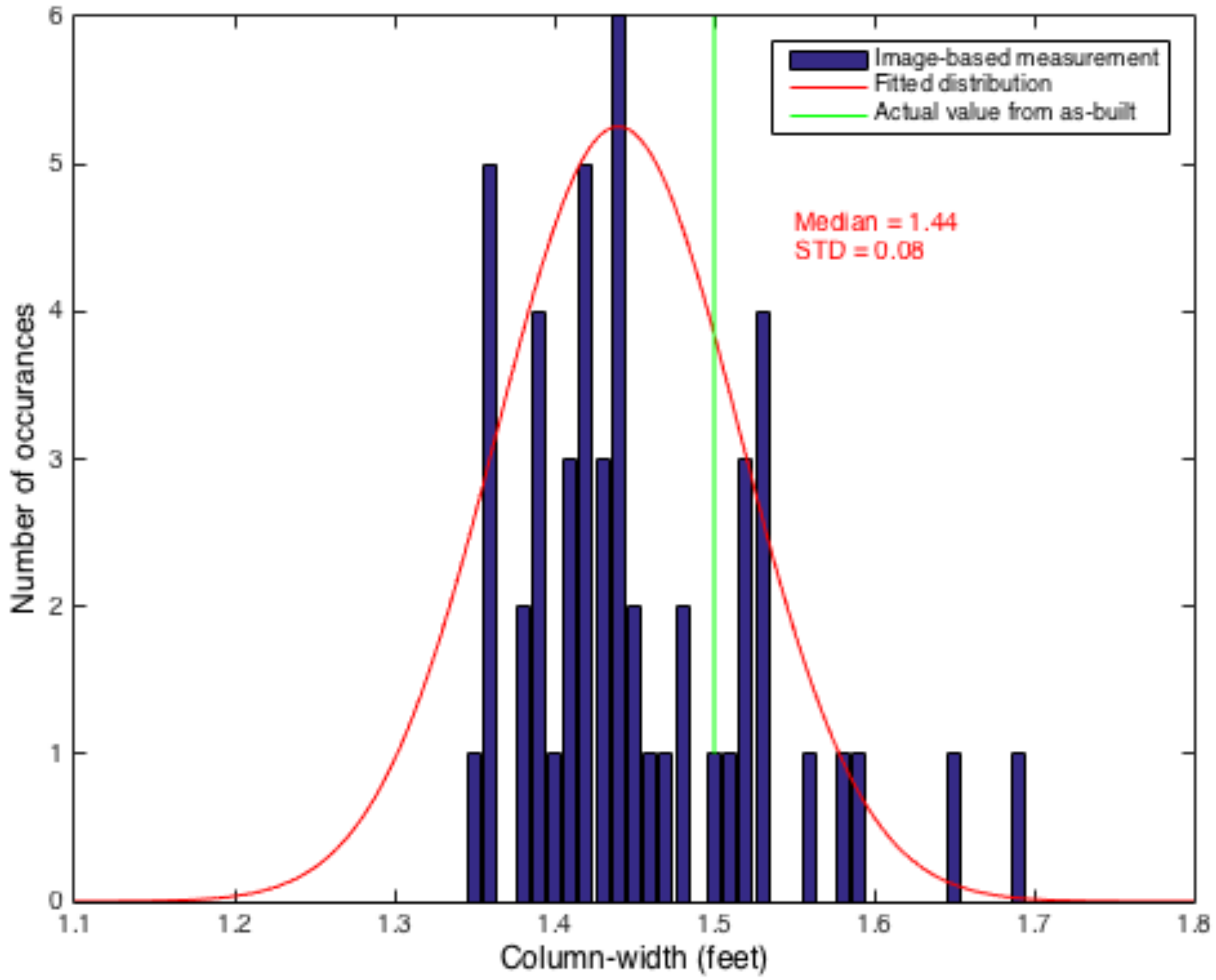




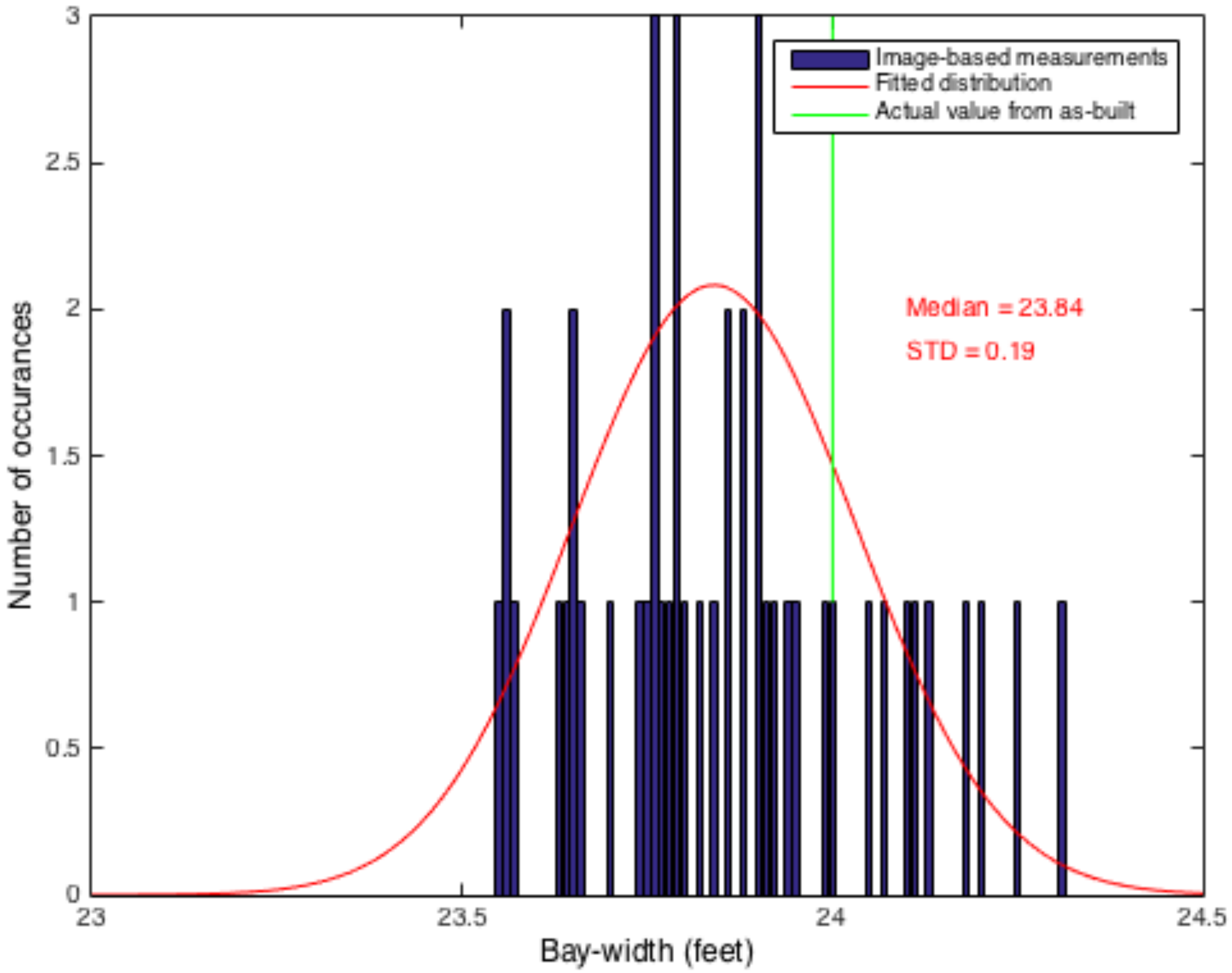




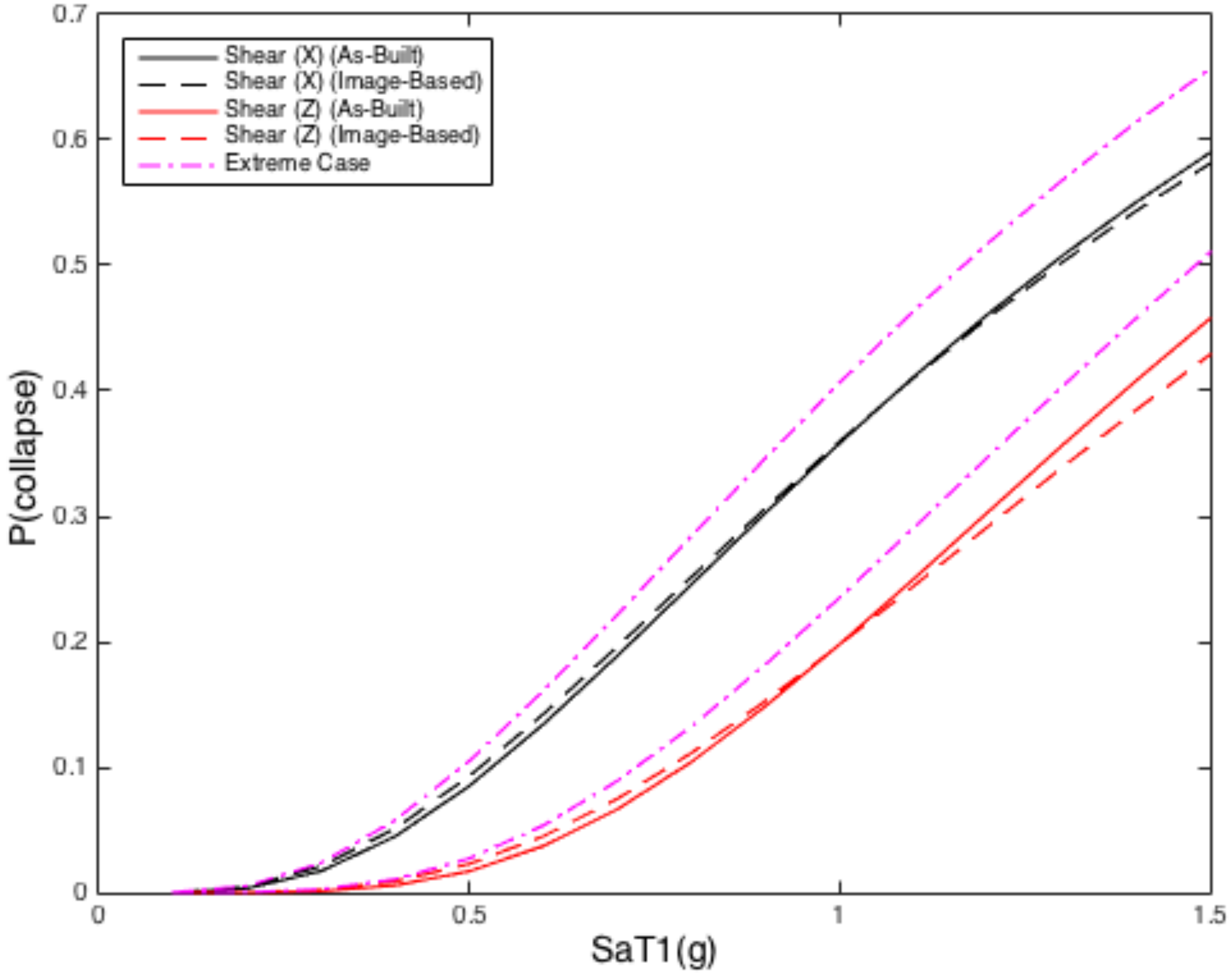
Building models from image data



Building models from image data



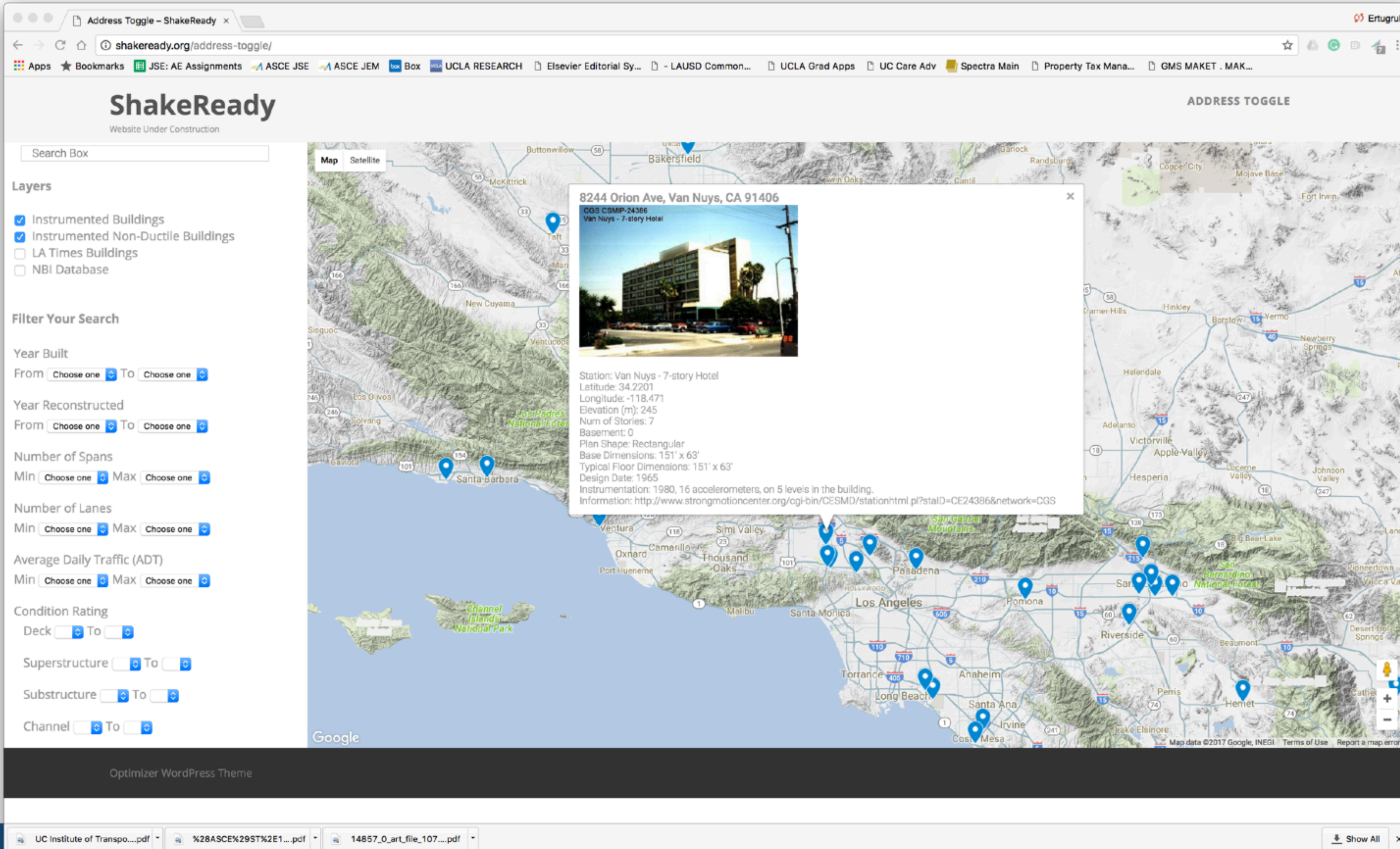
Building models from image data



ShakeReady

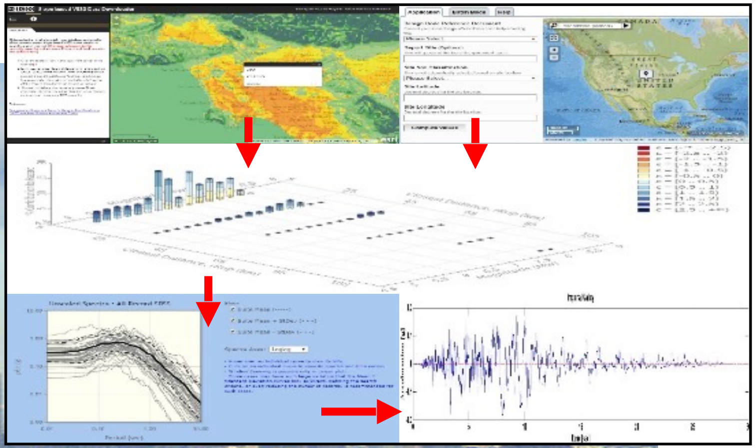
a user interface under development

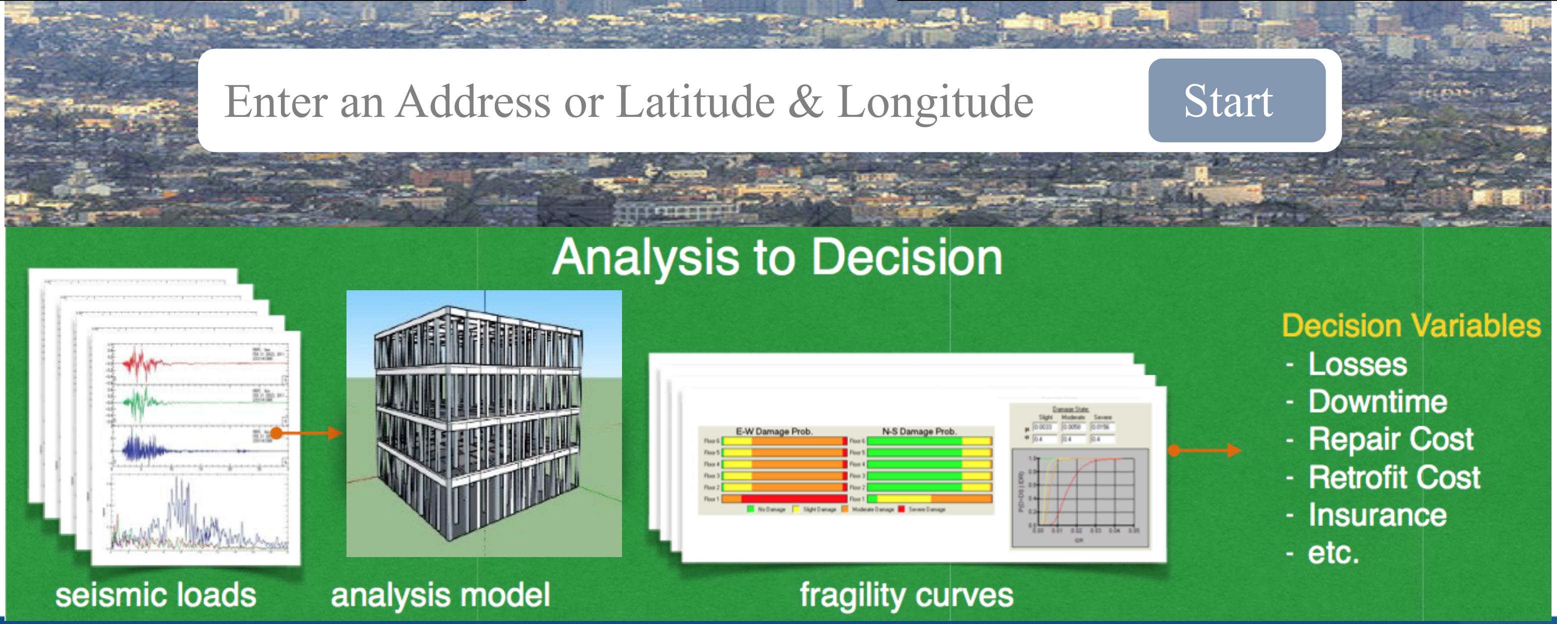
Building inventories



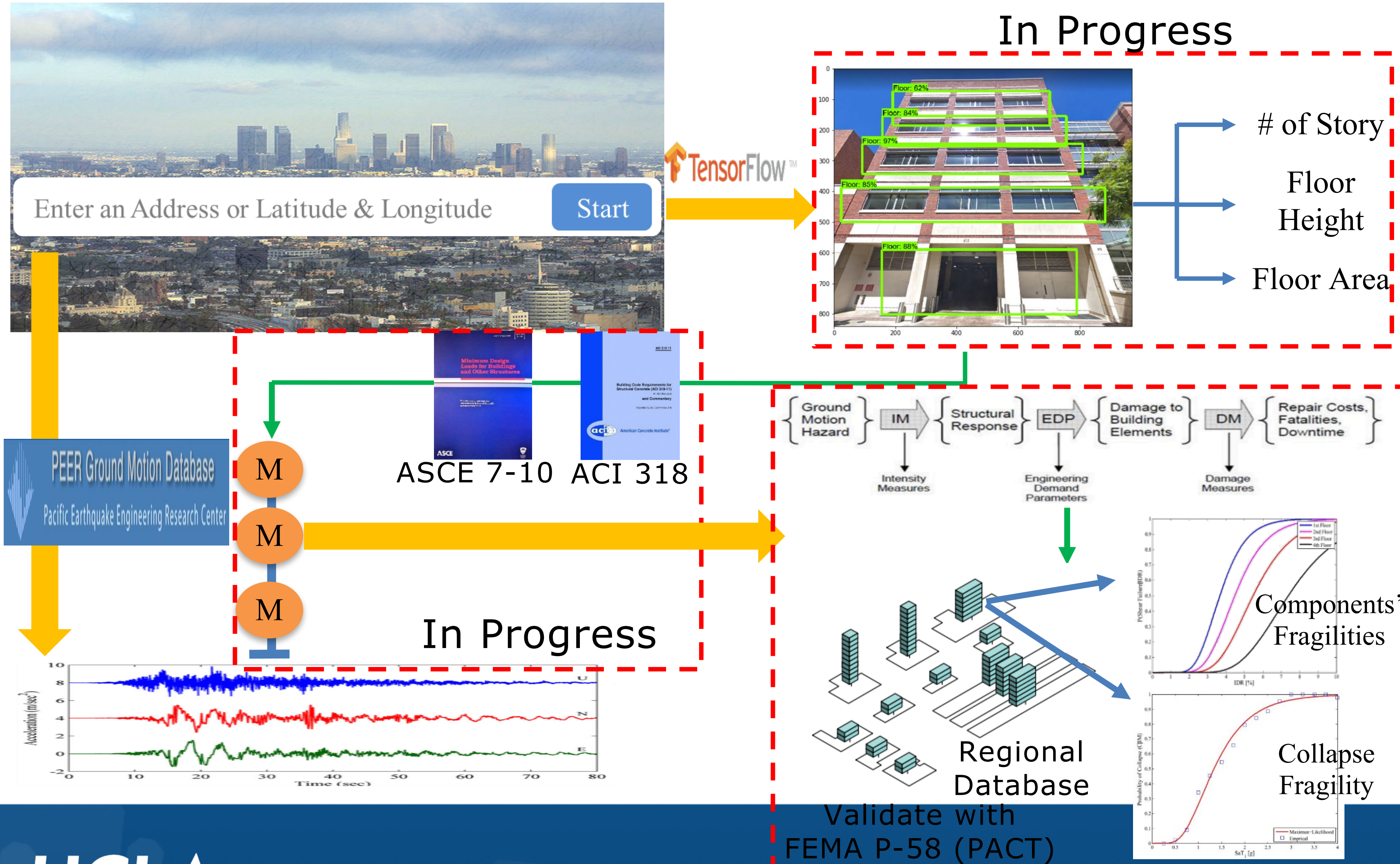
Building inventories





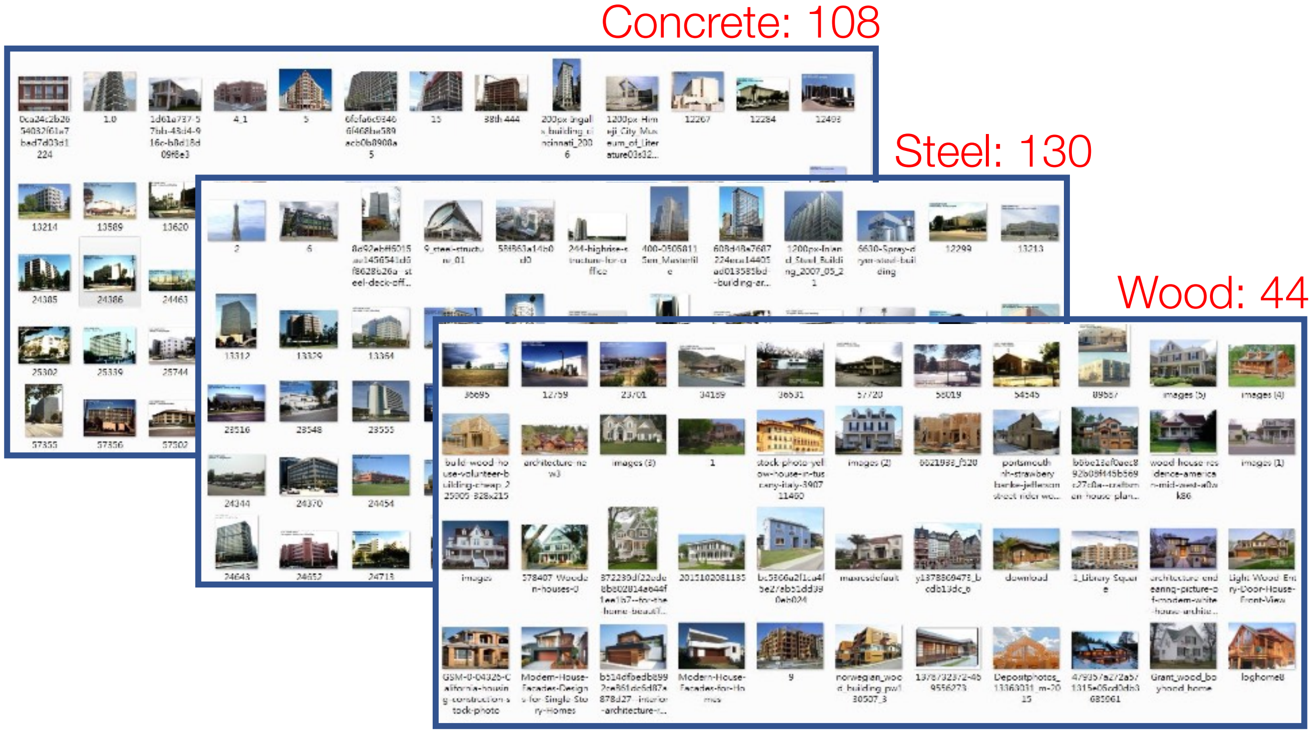


Overview of the toolbox



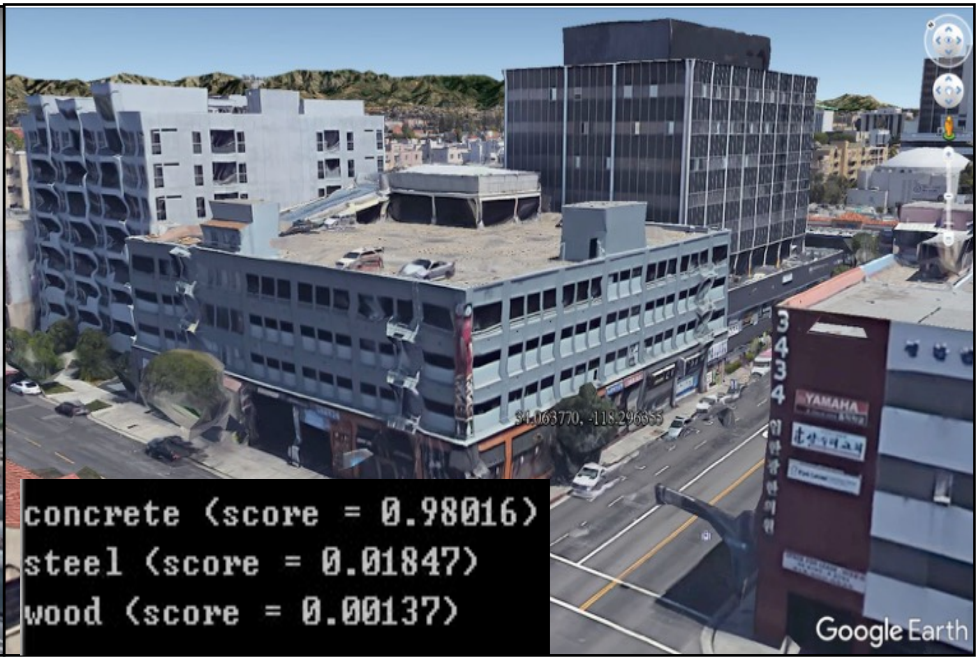
Machine learning

- A well-labeled training set is an important ingredient in image recognition to avoid overfitting.
- Center of Strong Motion Data (CESMD) was used to obtain the labeled image set.



A parking structure from the *LA Times* database





Occupancy	Parking	**Story**	4
Latitude	34.06364	**Square Footage**	114,985
Longitude	-118.29581	**Structural Type**	Concrete Frame with Unreinforced Wall
Address	3417, West, 6th Street	**Year of Built**	1973

A parking structure from the *LA Times* database

Using the *measuring tool* in GoogleEarth, geometric parameters were obtained, and their median values were utilized for generating the analysis model

	Mean (in)	Median (in)	SD (in)
Column Width	13.54	13.58	2.03
Column Depth	13.38	13.87	1.95
Beam Depth	16.2	15.33	2.44
Beam Width	N.A.	N.A.	N.A.
1st Floor Height	198.78	202.28	9.33
Typical Floor Height	81	81.86	7.27
Exterior Span	147.6	144.02	13.1
Interior Span	242.22	241.84	6.04
Slab Thickness	10.44	10.57	2.48

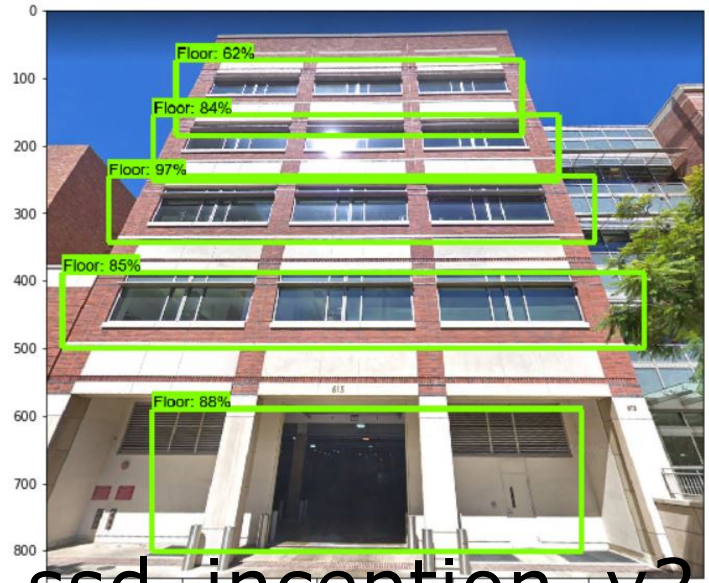
Image to Model

ssd_mobilenet_v1

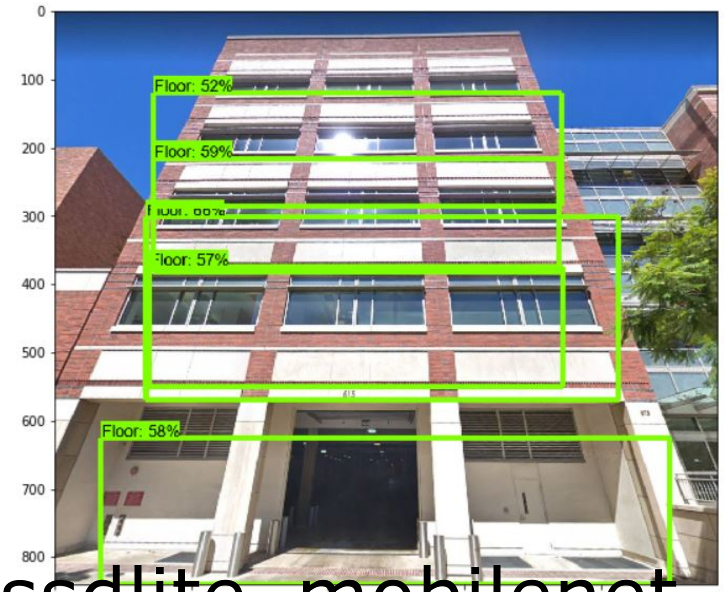


ssd_mobilenet_v2



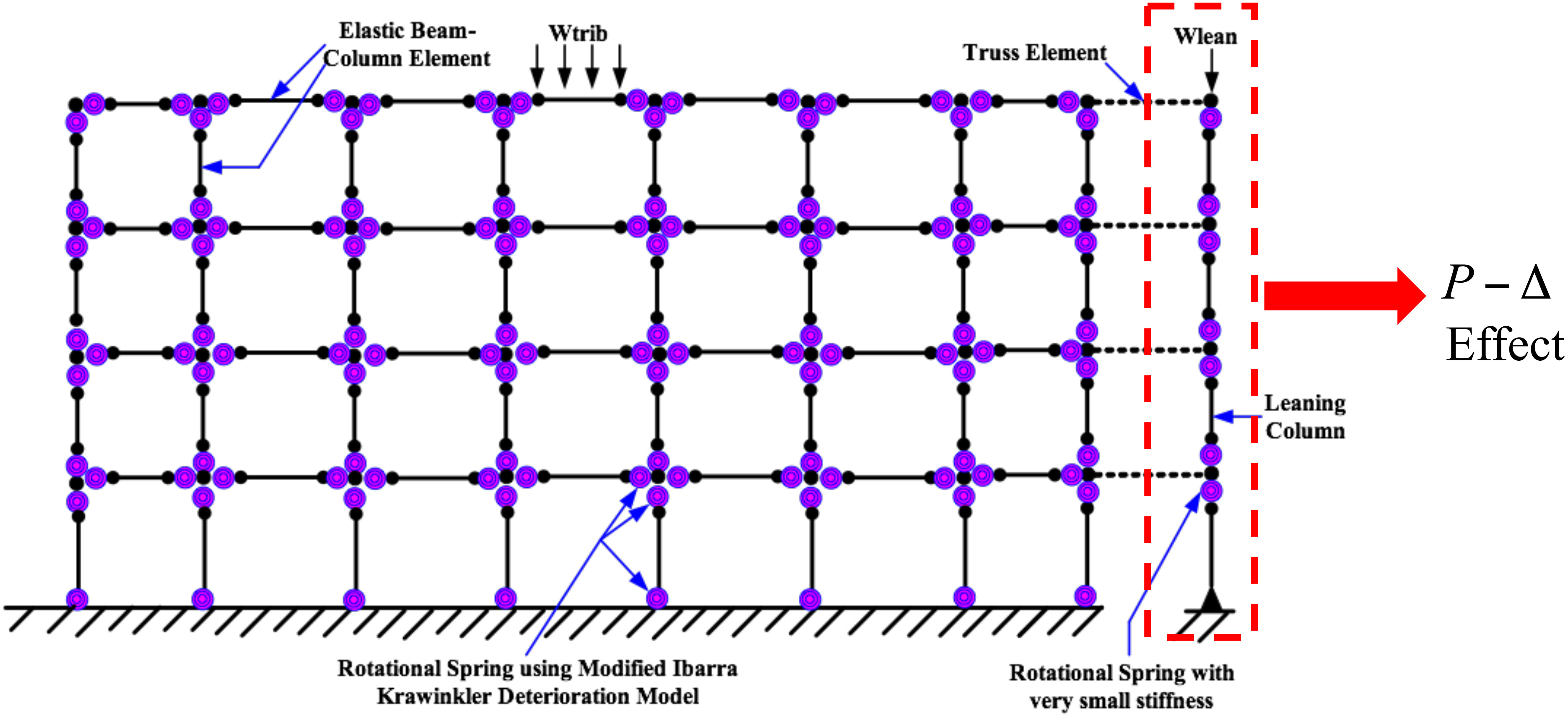


ssd_inception_v2

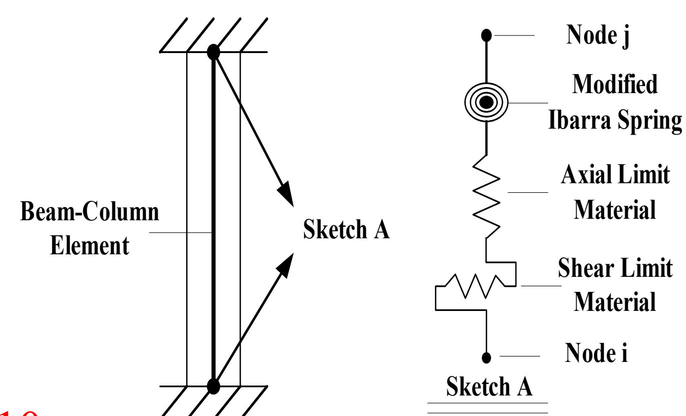


ssdlite_mobilenet_v2

UCLA

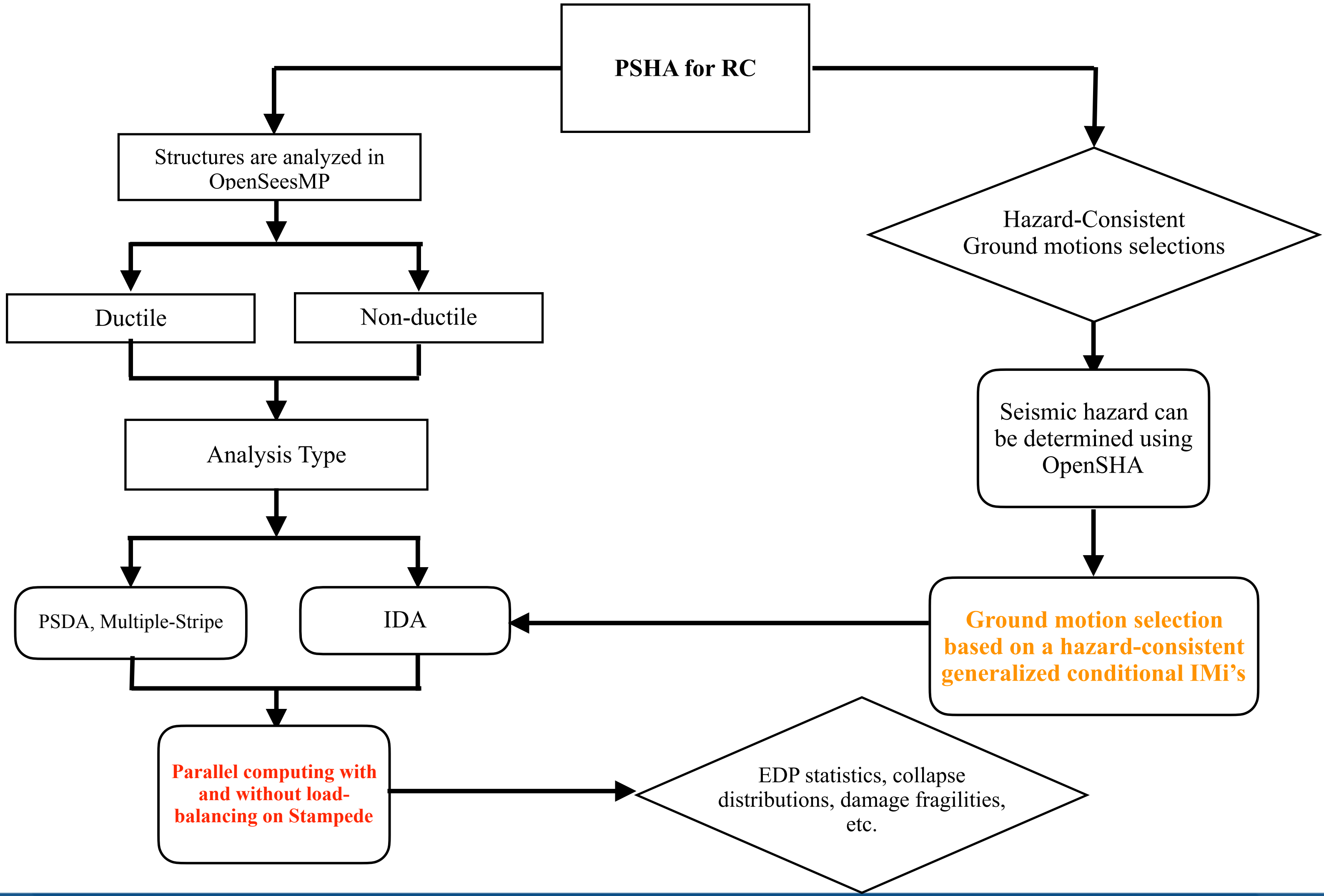


Component	Dimensions	Longitudinal Reinforcement		ρ_{long}	Transverse Reinforcement	$\rho_{transverse}$
Column	13"×13"	8#6		0.02	#4@12" (3-legs)	0.0043
Beam	13"×16"	Top	Bottom	0.017	#4@13" (2-legs)	0.0021
		4#7	4#7			

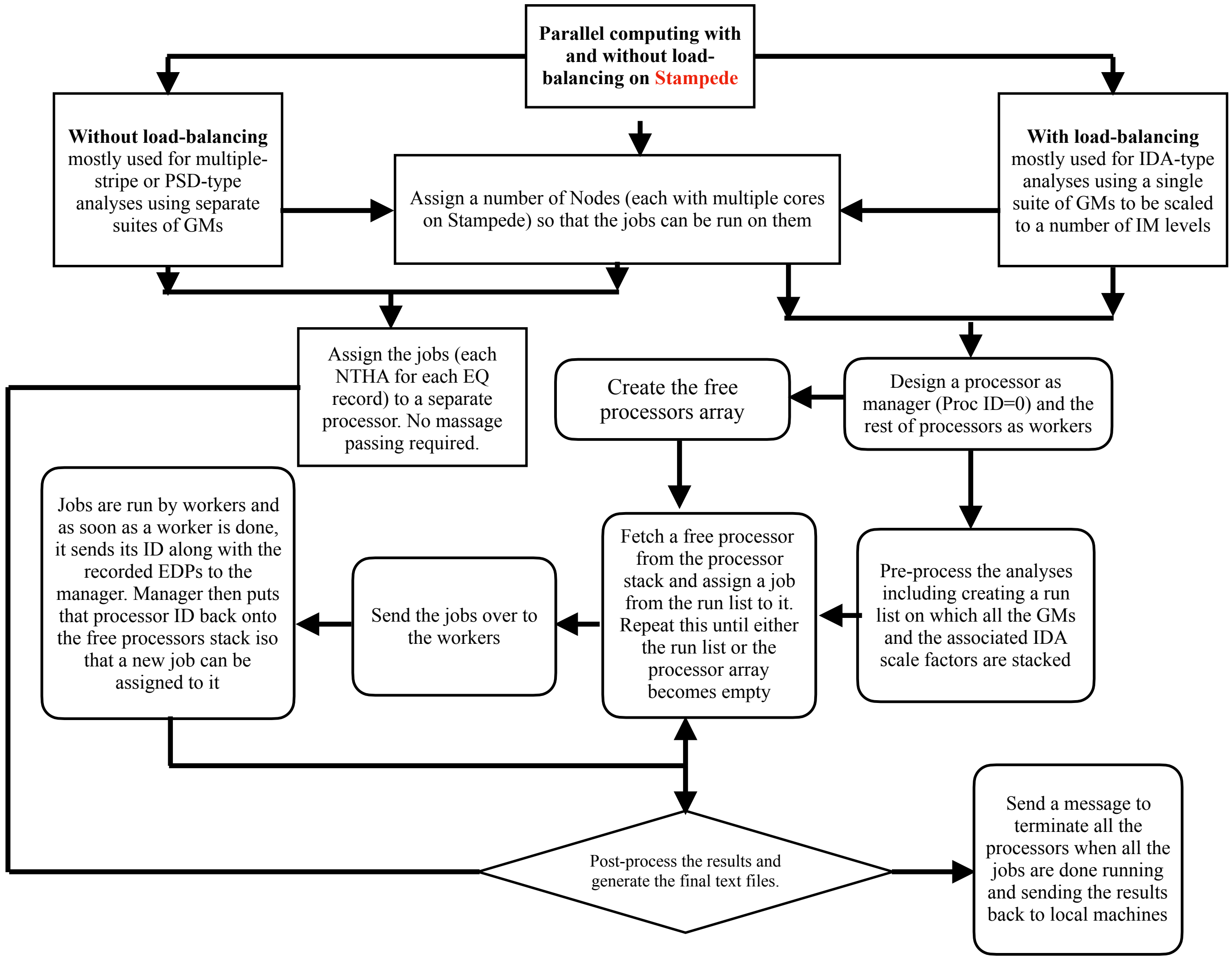


- Longitudinal bars were designed by following ACI 318-14.
- Transverse bars were designed by following ACI 318-63.
- Loads were defined by following ACI 318-14 and ASCE 7-10.

Generic workflow (largely scripted)

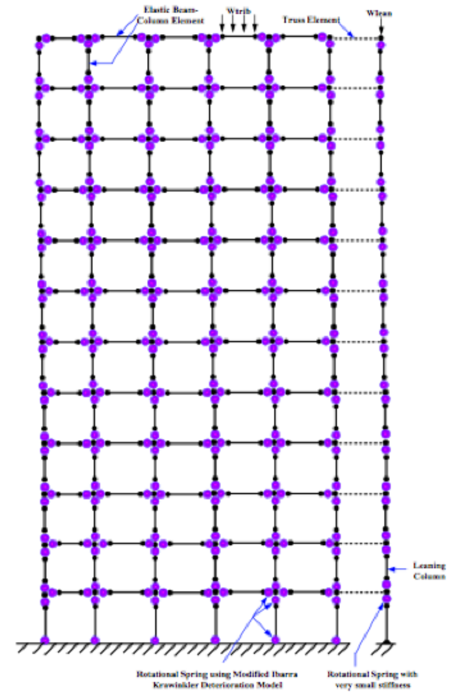


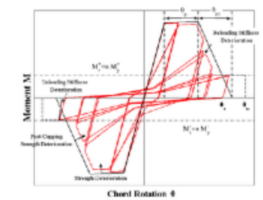
Management of parallel runs (fully scripted)



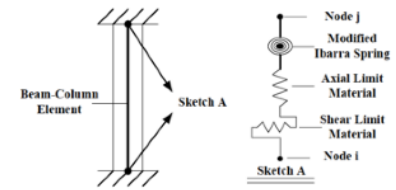
What the cloud brings …

- 1,200 NTHAs (12 sets of GMs with 100 records per set).
- 2,400 NTHAs for each building (ductile and non-ductile).
- Used only 2 nodes on STAMPEDE (68 processors on each node).
- Took ~3 hours for all the 2,400 NTHAs to complete. So on average 0.075 min per each run.
- On a serial computer, each NTHA would take ~4 mins, so for 2,400 runs, it would have taken 160 hours (i.e., ~7 days) to be completed .





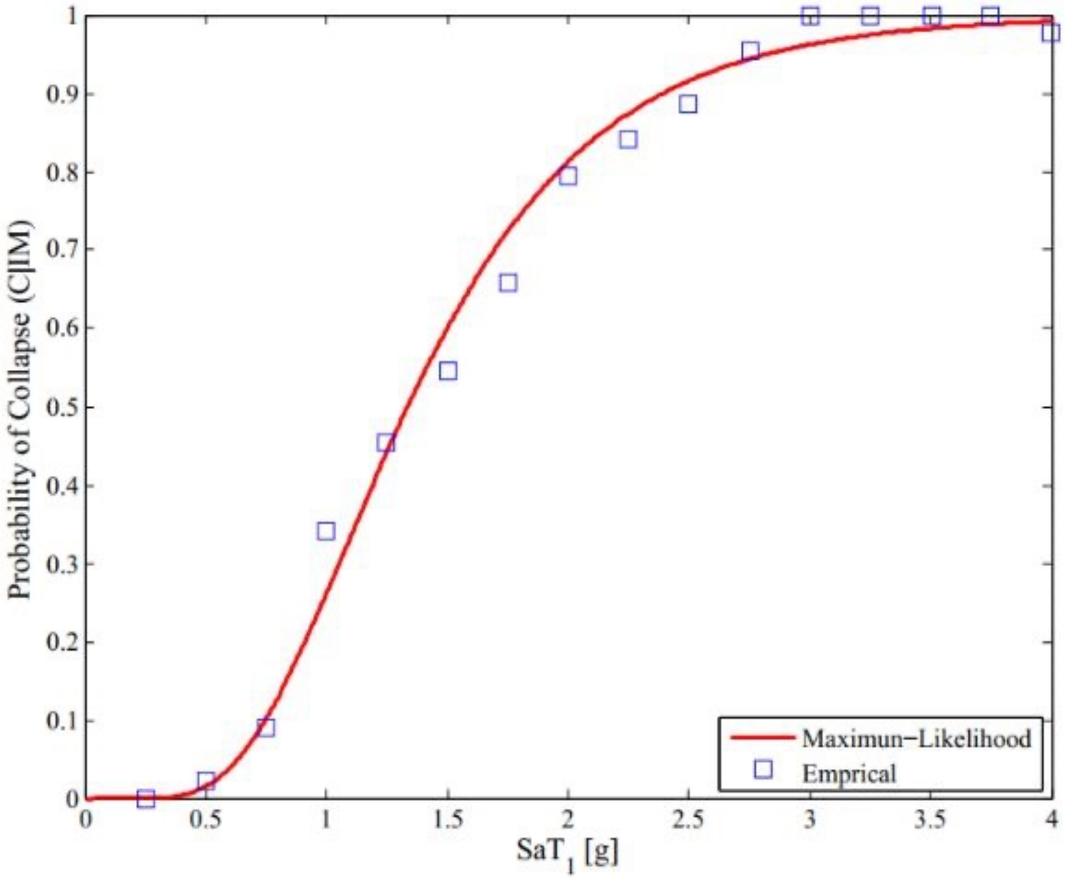
Modified Ibarra-Medina-Krawinkler deterioration model



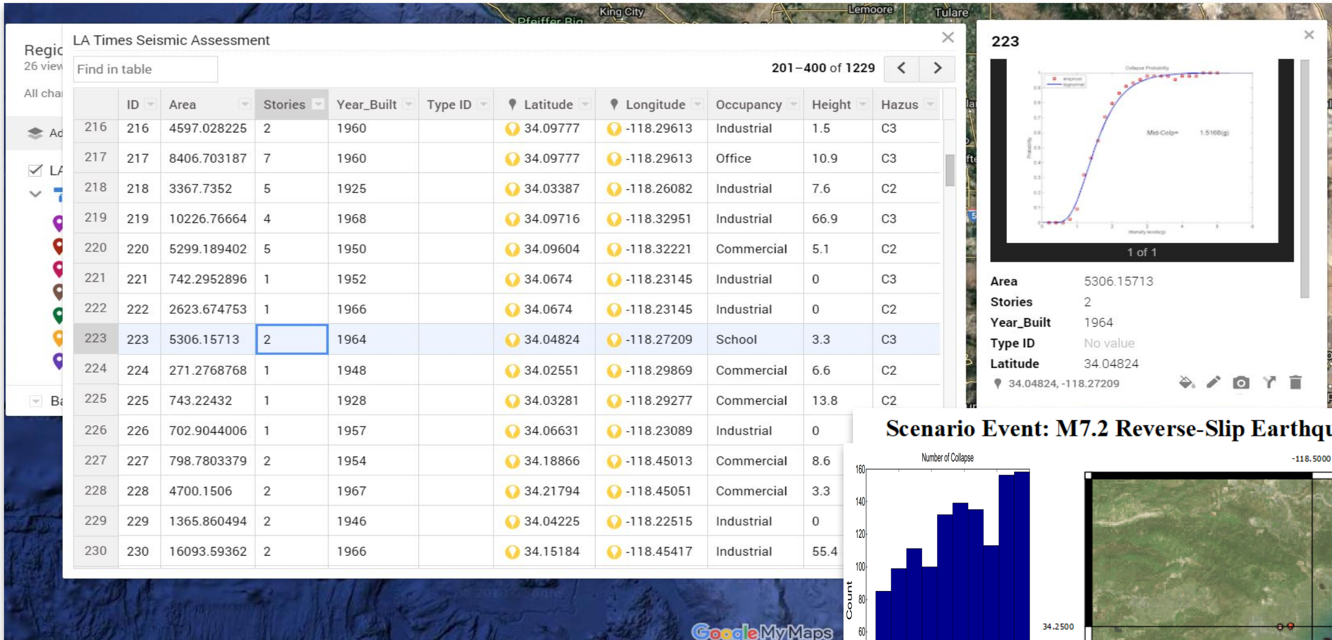
shear-axial elements for NDRCBs

- Empirical collapse probability, assuming IDR=5% as the collapse limit state

$$\lambda(DV) = \iiint G\langle DV \mid DM \rangle dG\langle DM \mid EDP \rangle dG\langle EDP \mid IM \rangle d\lambda(\text{IM})$$

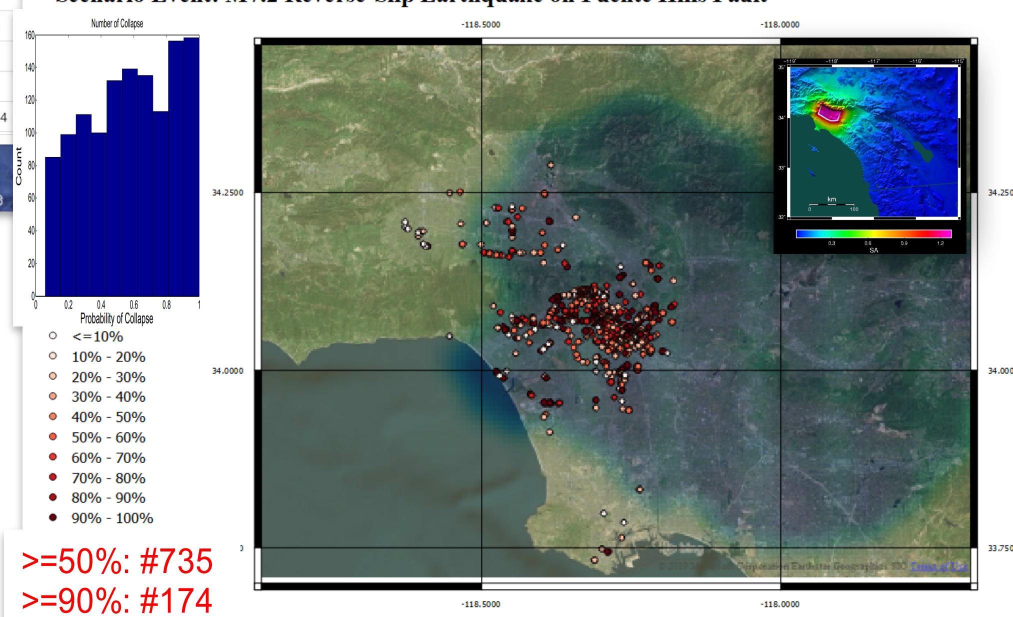


Non-ductile reinforced concrete buildings under a scenario event



	ID	Area	Stories	Year_Built	Type ID	Latitude	Longitude	Occupancy	Height	Hazus
216	216	4597.028225	2	1960		34.09777	-118.29613	Industrial	1.5	C3
217	217	8406.703187	7	1960		34.09777	-118.29613	Office	10.9	C3
218	218	3367.7352	5	1925		34.03387	-118.26082	Industrial	7.6	C2
219	219	10226.76664	4	1968		34.09716	-118.32951	Industrial	66.9	C3
220	220	5299.189402	5	1950		34.09604	-118.32221	Commercial	5.1	C2
221	221	742.2952896	1	1952		34.0674	-118.23145	Industrial	0	C3
222	222	2623.674753	1	1966		34.0674	-118.23145	Industrial	0	C2
223	223	5306.15713	2	1964		34.04824	-118.27209	School	3.3	C3
224	224	271.2768768	1	1948		34.02551	-118.29869	Commercial	6.6	C2
225	225	743.22432	1	1928		34.03281	-118.29277	Commercial	13.8	C2
226	226	702.9044006	1	1957		34.06631	-118.23089	Industrial	0	
227	227	798.7803379	2	1954		34.18866	-118.45013	Commercial	8.6	
228	228	4700.1506	2	1967		34.21794	-118.45051	Commercial	3.3	
229	229	1365.860494	2	1946		34.04225	-118.22515	Industrial	0	
230	230	16093.59362	2	1966		34.15184	-118.45417	Industrial	55.4	

Scenario Event: M7.2 Reverse-Slip Earthquake on Puente Hills Fault

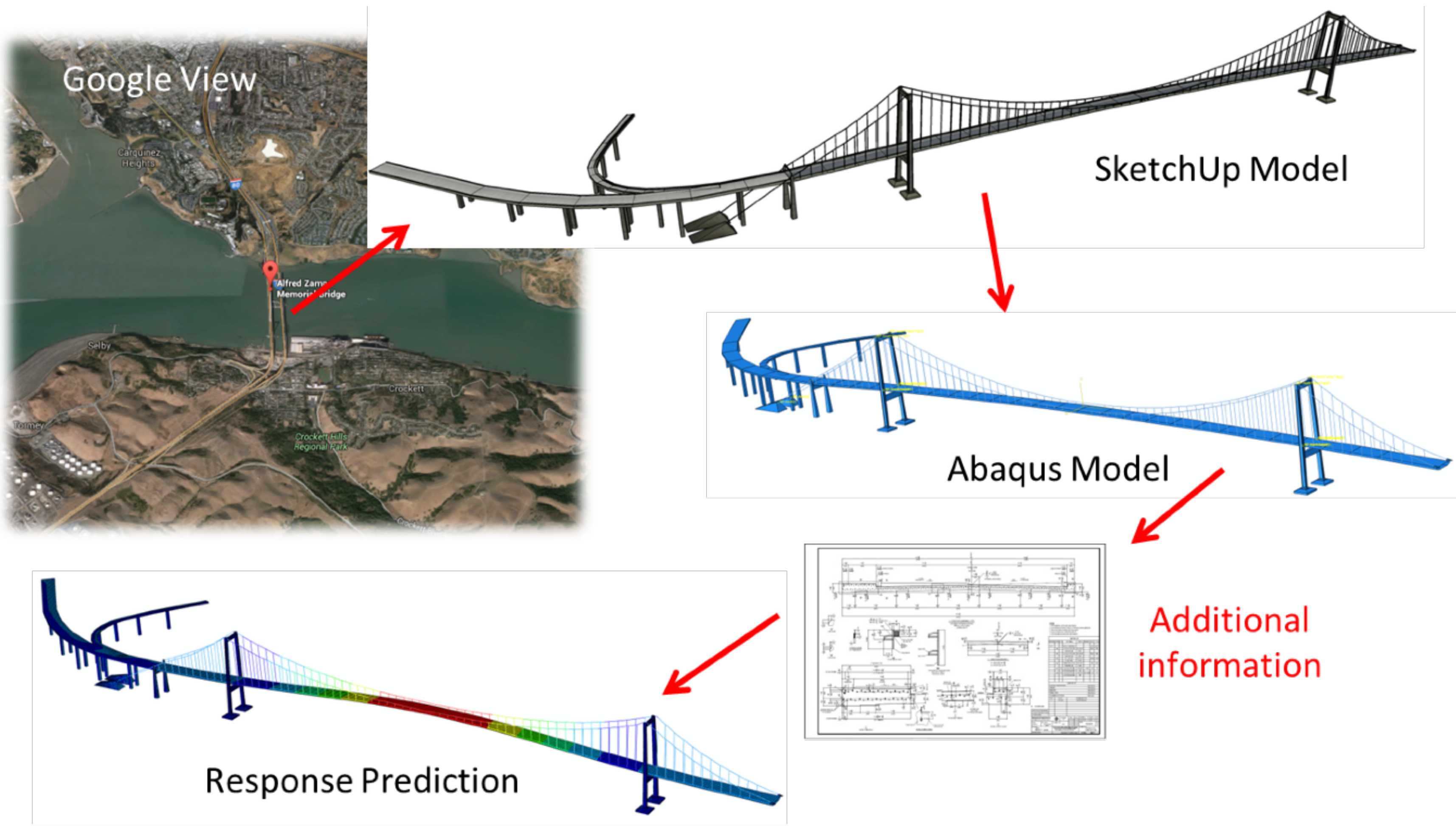


>=50%: #735
>=90%: #174

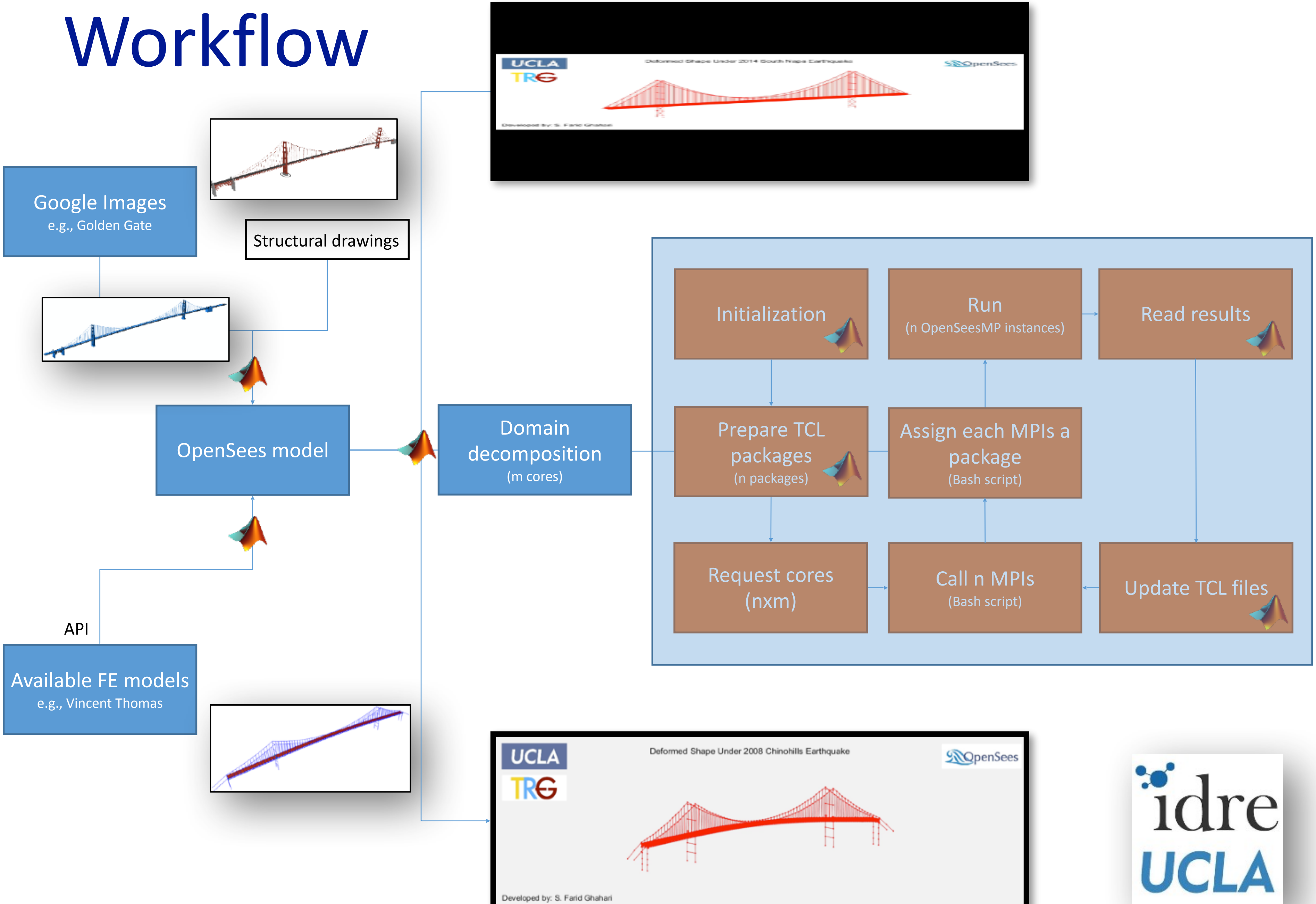
complex bridges



Models

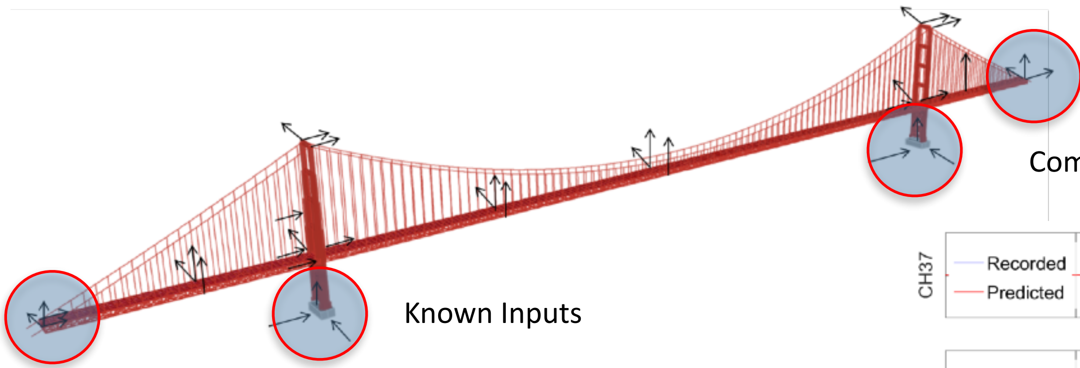

Google View
Carquinez Heights
Selby
Crockett
Crockett Hills Regional Park
SketchUp Model
Abaqus Model
Additional information
Response Prediction

Workflow

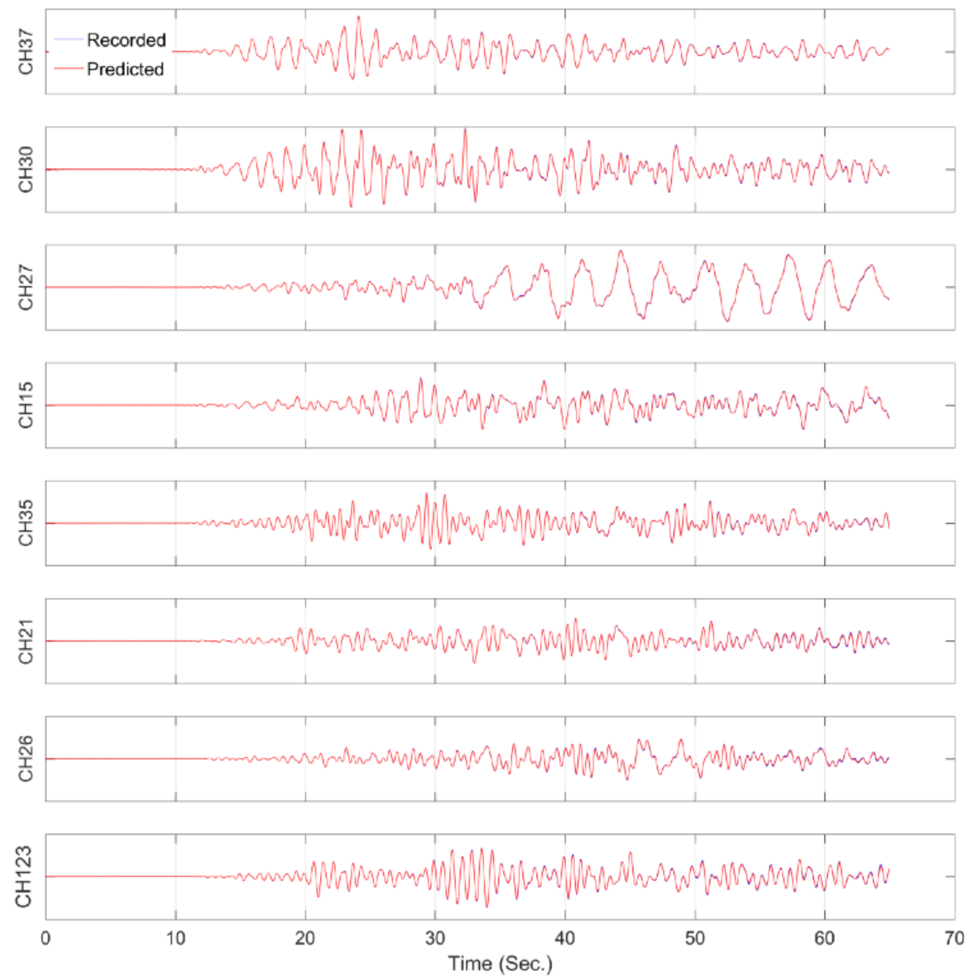


Google Images
e.g., Golden Gate
Structural drawings
OpenSees model
API
Available FE models
e.g., Vincent Thomas
Domain decomposition
(m cores)
Initialization
Run
(n OpenSeesMP instances)
Read results
Prepare TCL packages
(n packages)
Assign each MPIs a package
(Bash script)
Request cores
(nxm)
Call n MPIs
(Bash script)
Update TCL files
UCLA
TRG
OpenSees
Deformed Shape Under 2008 Chinohills Earthquake
Developed by: S. Farid Ghahari
idre
UCLA

Verification: Input-Output

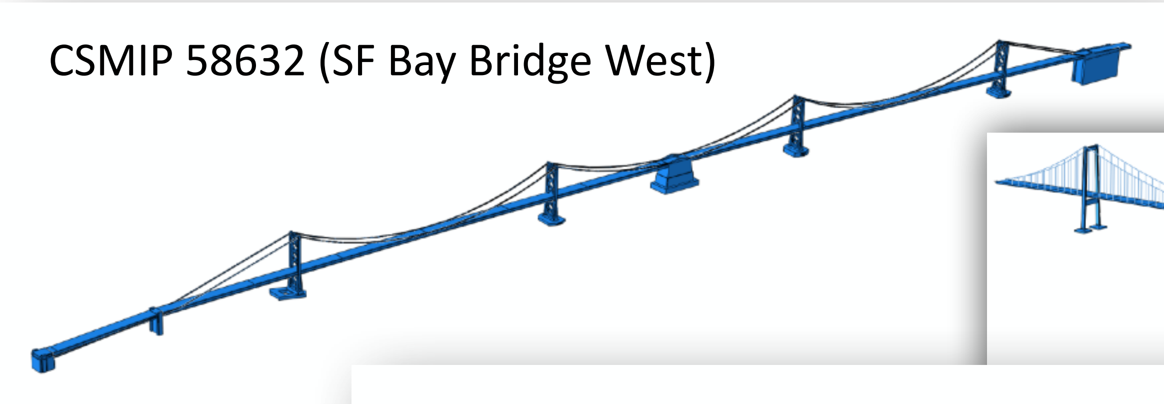


Comparison between recorded (simulated) and predicted responses at selected channels

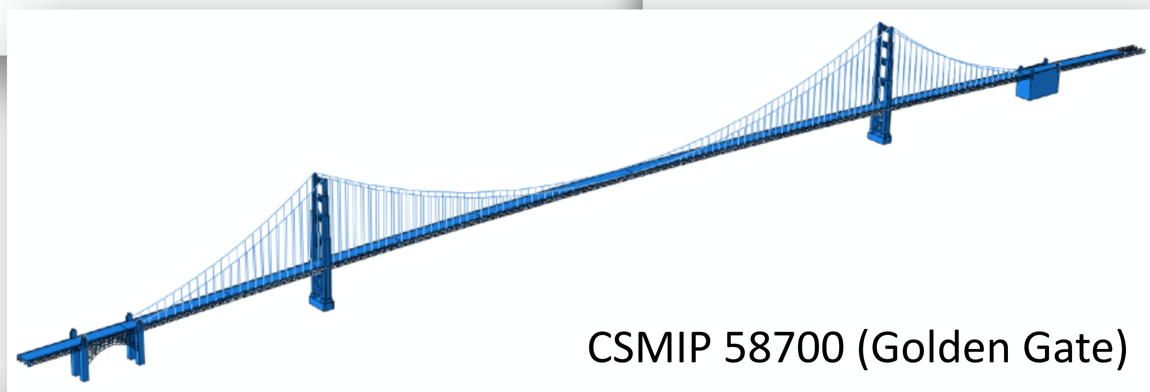


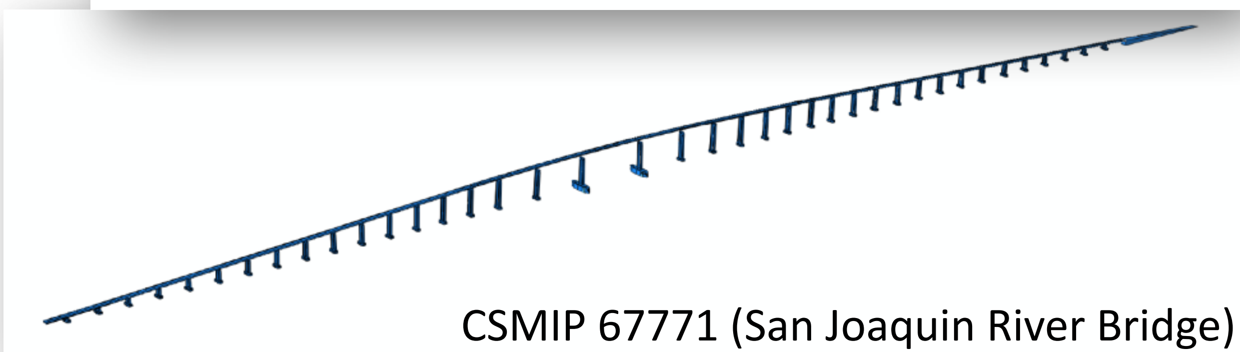
Parameter	Initial Error (%)	Final Error (%)
Towers' *E*	50	0.03
Cables' *E*	50	0.04
Chords' *E*	50	0.23
Bottom Bracings' E	50	1.59
Mass-Prop. Damping	50	2.38
Stiffness-Prop. Damping	50	13.76

Example Finite Element Models









Quo Vadis?

- Further develop Image-to-Model Capabilities
- Complete user-interface (GIS-integrated website)
- Improve metadata harvesting and processing tools
  - Develop meta-data templates for different bridge types (guided by the I-405 regional study)
  - Develop component (e.g., column) databases + an Expert System
  - Extend NBI query capabilities
  - Add AASHTO database query capabilities
- Develop CA bridge inventory (recruit and train undergrad interns)
- Automate and streamline Cloud Computing
  - Improve computational efficiency by more intelligent probing of the response space using techniques such as Latin Hypercube Sampling (~~Monte Carlo~~)


thank you
TRG @ UCLA